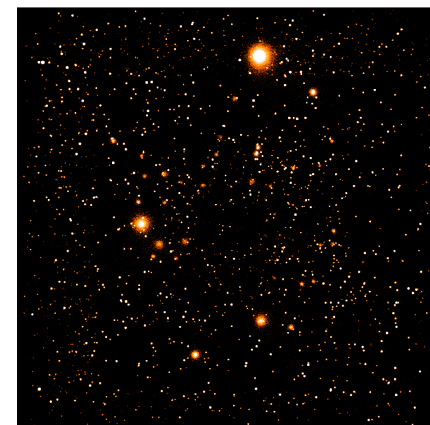
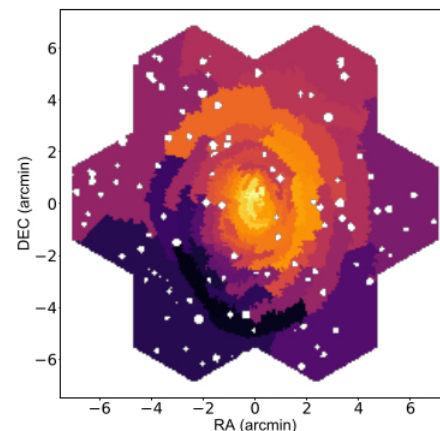
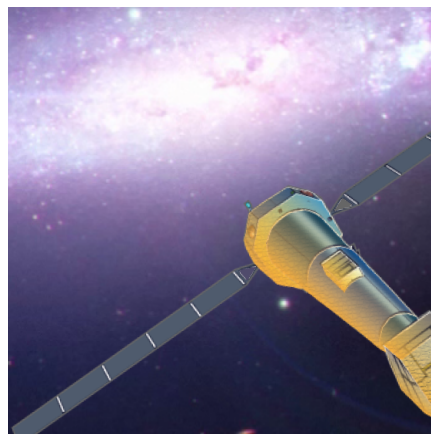


# ATHENA

## Learning about AGN with Athena



Francisco J. Carrera (IFCA)

Instituto de Física de Cantabria  
IFCA (CSIC-UC)  
Santander, Spain



EXCELENCIA  
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DE MAEZTU  
Instituto de Física de Cantabria



V Meeting of AGN research in Spain,  
IFCA (CSIC-U. Cantabria), July 2019

# Contents

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- *Athena*: Mission concept & payload
- The *Athena* science theme: Hot and Energetic Universe
- Example AGN topics
- Synergies
- Project development status
- Outlook

Thanks to:

- The *Athena* Science Study Team:  
M. Guainazzi, K. Nandra, D. Barret,  
J.W. den Herder, A. Decourchelle,  
A.C. Fabian, H. Matsumoto, L. Piro,  
R. Smith, R. Willingale
- X. Barcons for the initial presentation
- Athena Working Groups and Instrument Teams
- Athena Community Office



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IFCA (CSIC-U. Cantabria), July 2019



# Advanced Telescope for High-Energy Astrophysics

- Second Large (L2) mission of ESA Cosmic Vision
- Science theme: The Hot and Energetic Universe:
  - How does ordinary matter assemble into the large-scale structure we see today?
  - How do black holes grow and shape the Universe?
- Next generation X-ray observatory designed to address science theme
- Broad impact across many areas of astrophysics
- More info at [www.the-athena-x-ray-observatory.eu](http://www.the-athena-x-ray-observatory.eu)



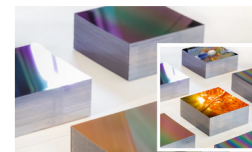
## *The Athena X-ray Observatory: Community Support Portal*



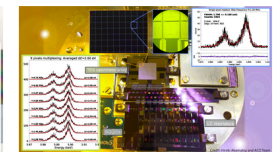
## Latest activities & news



"Exploring the Hot and Energetic Universe" conference, 24-27 September, 2018



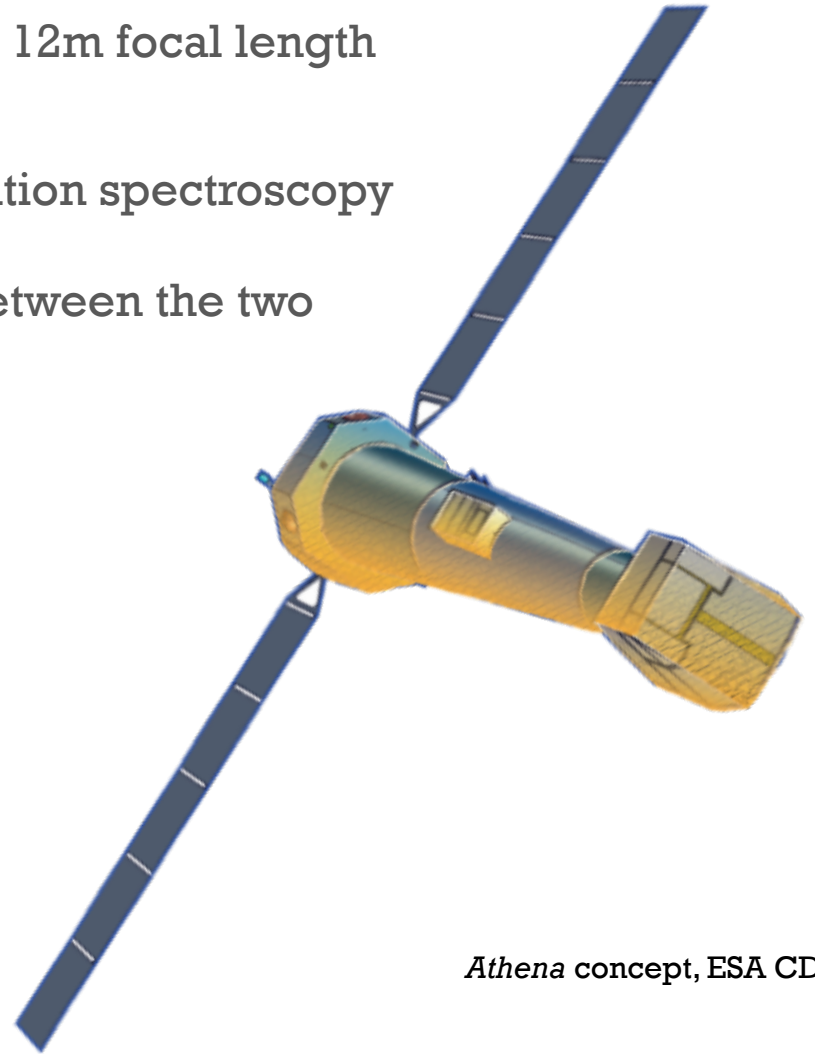
Newsletter #5 (June 2018)



#AthenaNuggets: Reading X-ray detector signals out in MHz frequency space

# Athena mission concept

- Single telescope, using Si pore optics. 12m focal length
  - WFI sensitive imaging & timing
  - X-IFU spatially resolved high-resolution spectroscopy
- Movable mirror assembly to switch between the two instruments
- Launch early 2030s, Ariane 6.4
- L2 halo orbit (TBC)
- Lifetime: 4 yr +Possible extensions



*Athena concept, ESA CDF*

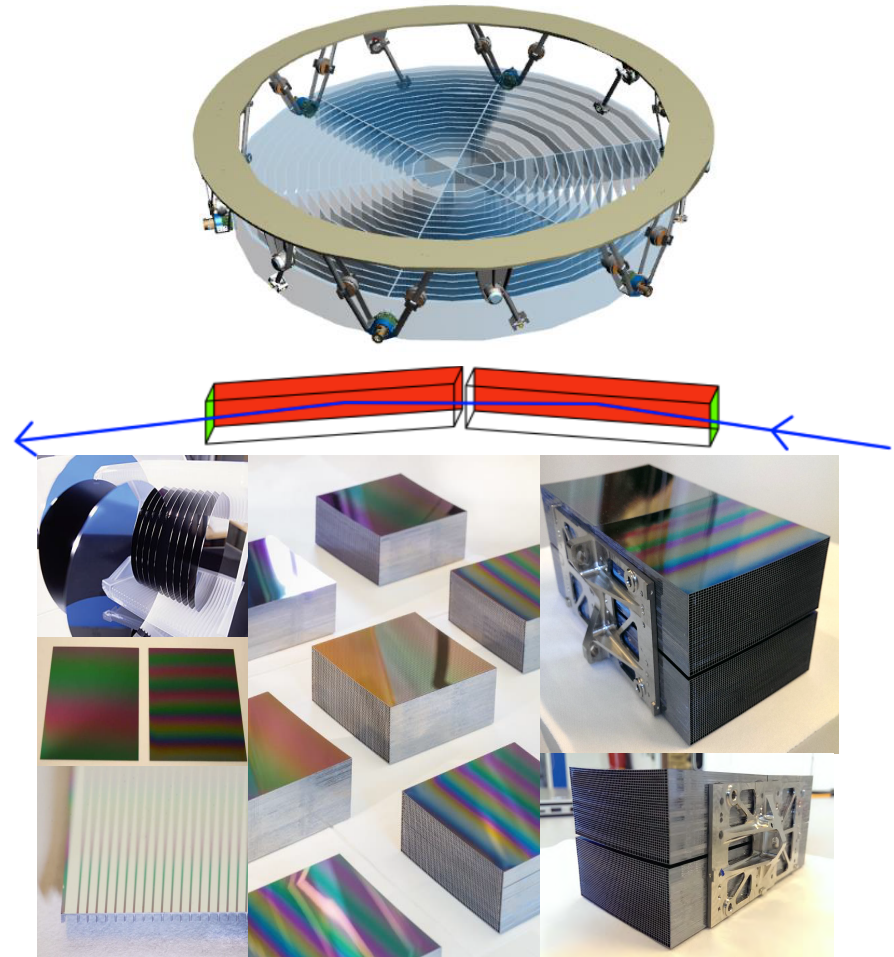
# The Athena X-ray optics

## ■ Athena optics development:

- Light-weight Si-pore optics
- Grazing incidence optics with Wolter-Schwarzschild type I geometry optimised to provide wide flat field imaging
- Vigorous development programme on-going

## ■ Expected Performance:

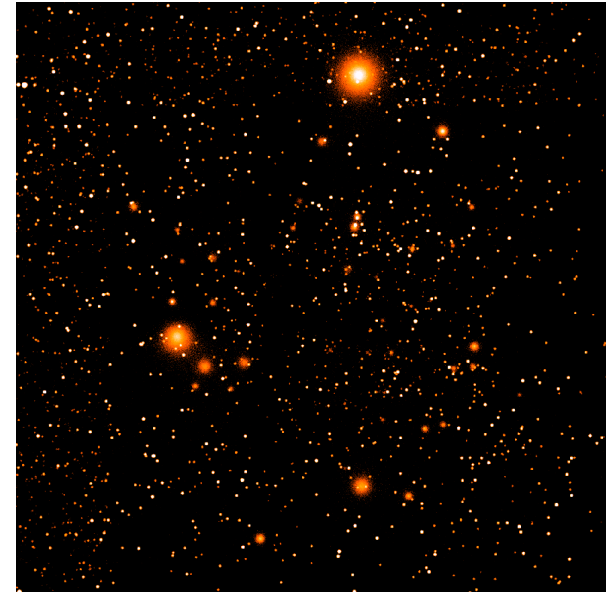
- $5''$  HEW on-axis
- Graceful degradation off-axis  
 $\text{HEW} < 10'' @ 30'$
- $\geq 1.4 \text{ m}^2$  effective area @ 1 keV  
 $0.25 \text{ m}^2$  effective area @ 6 keV



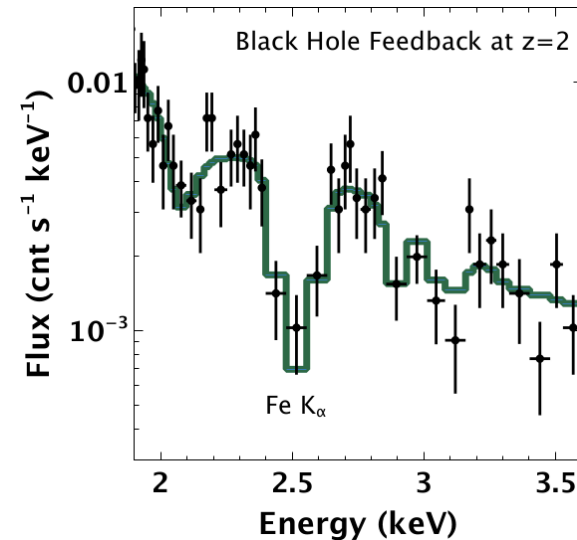
Willingale, Pareschi et al. 2013, arXiv: 1308.6785  
Cosine/ESA

# Wide Field Imager (WFI)

- Silicon Active Pixel Detector based on DEPFET technology
- Key performances:
  - $<80$ - $<170$  eV spectral resolution @1-6 keV
  - $2.2''$  pixel size (PSF oversample)
  - Field of view:  $40' \times 40'$  square
  - Separate chip for fast readout of brightest sources
  - Readout speed up to  $\sim 30$  MHz
- Consortium led by MPE, with other European partners (DE, AT, DK, FR, IT, PL, UK, CH, P & GR) and NASA
- Optimized for sensitive wide-field imaging and intermediate resolution spectroscopy, up to very bright sources



Credit: A. Rau/WFI Team



Credit: WFI team.

<http://www.mpe.mpg.de/ATHENA-WFI/>



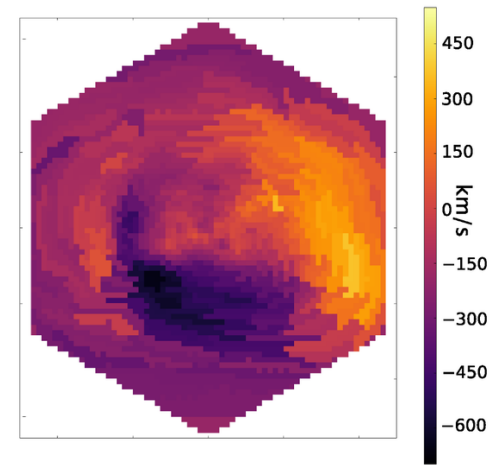
IFCA  
Instituto de Física de Cantabria

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DE MAEZTU

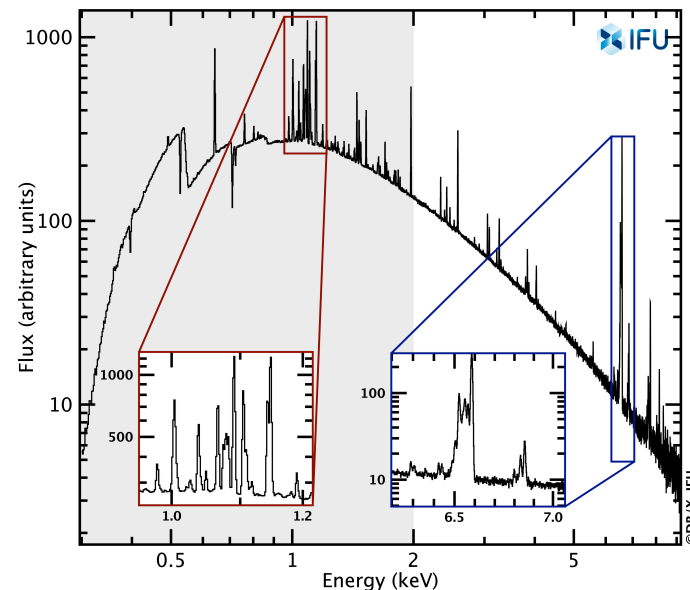


# X-ray Integral Field Unit (X-IFU)

- Cryogenic imaging spectrometer, based on Transition Edge Sensors, operated at 50 mK featuring an active cryogenic background rejection subsystem
- Key performance parameters:
  - 2.5 eV energy resolution <7 keV
  - FoV 5' diameter
  - Pixel size <5''
- Consortium led by IRAP/CNES-F, by IRAP/CNES-F, with Netherlands and Italy and further ESA member state contributions from Belgium, Czech Republic, Finland, Germany, Ireland, Poland, Spain, Switzerland and contributions from Japan and the United States
- Providing both spatially-resolved high spectral resolution and high count rate capability



Credit: X-IFU consortium (E. Cuchetti, IRAP)



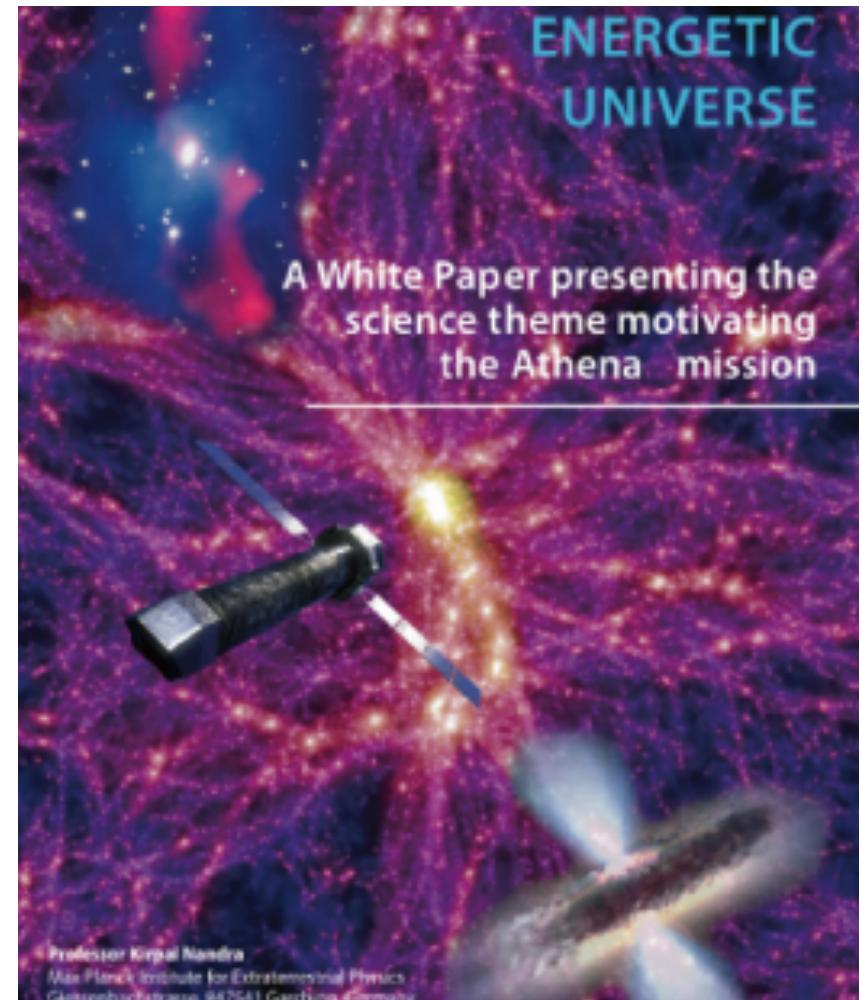
Credit: X-IFU consortium  
Courtesy: C. Pinto, A.C. Fabian





# The Hot and Energetic Universe

- The Hot Universe: How does ordinary matter assemble into the large-scale structures that we see today?
  - >50% of the baryons today are in a hot ( $>10^6$  K) phase
  - Now there are as many hot ( $> 10^7$  K) baryons in clusters as in stars over the entire Universe
- The Energetic Universe: How do black holes grow and influence the Universe?
  - Building a SMBH releases  $30\times$  the binding energy of a galaxy
  - 15% of the energy output in the Universe is in X-rays



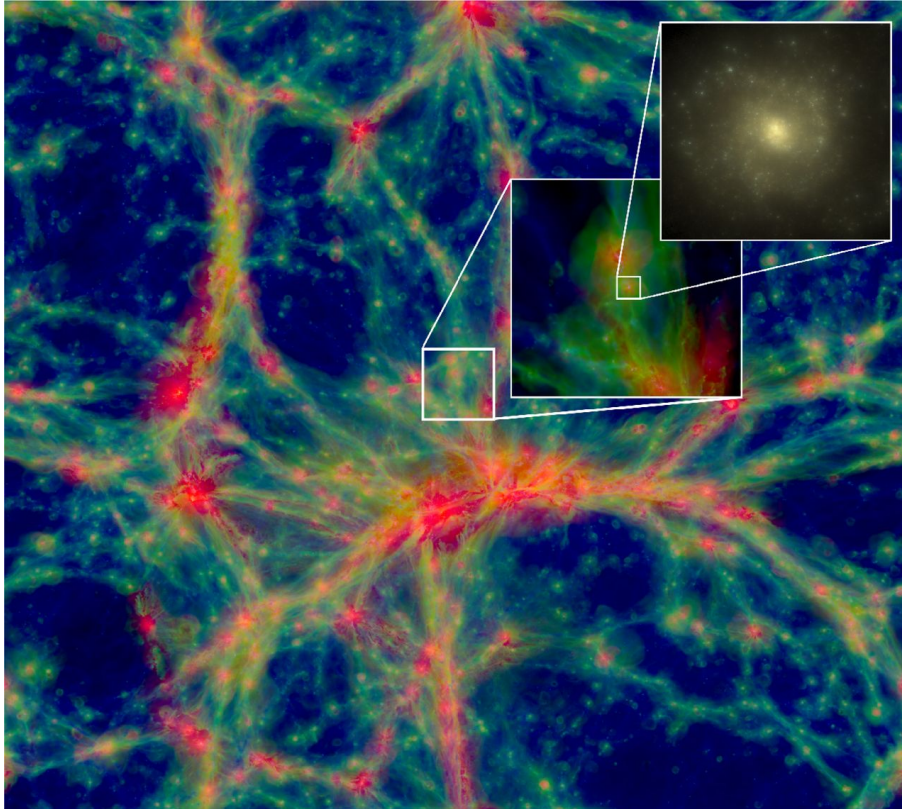
Nandra, Barret, Barcons et al. arXiv:1306.2307

V Meeting of AGN research in Spain,  
IFCA (CSIC-U. Cantabria), July 2019

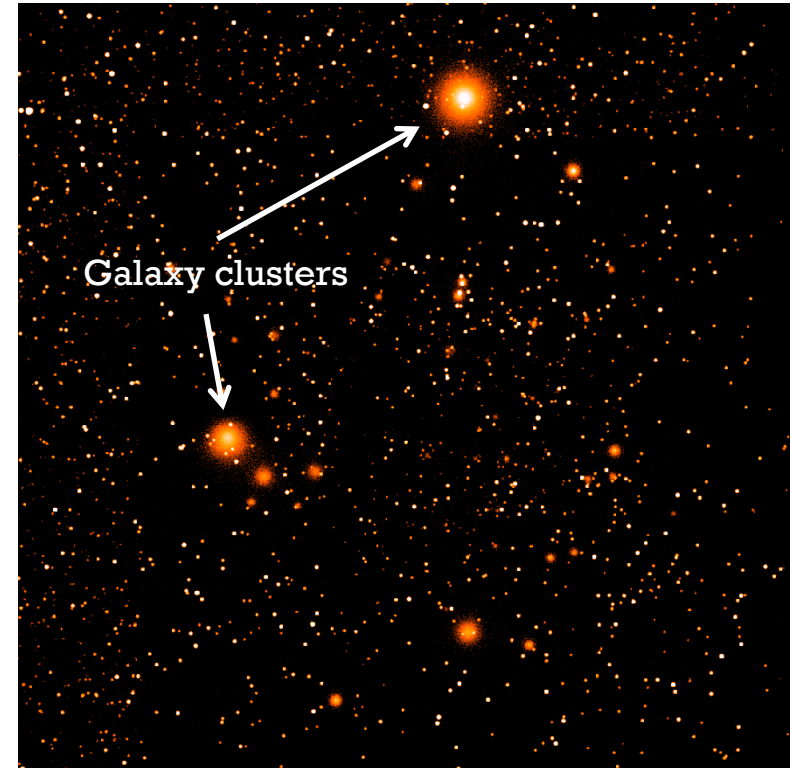
# The Hot Universe – baryonic assembly

EAGLE cosmological simulation

$T < 10^{4.5} \text{ K}$     $10^{4.5} \leq T \leq 10^{5.5} \text{ K}$     $T > 10^{5.5} \text{ K}$



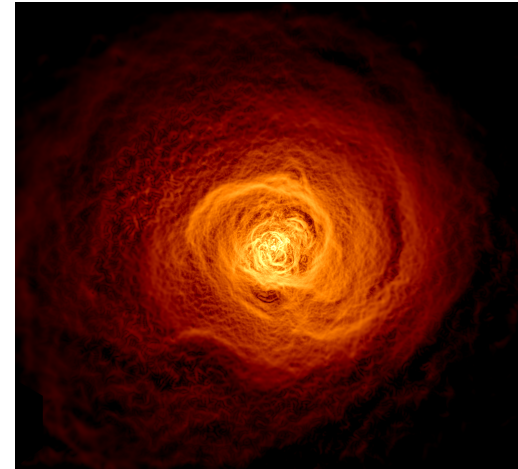
Schaye et al. 2015



Credit: A. Rau/WFI Team

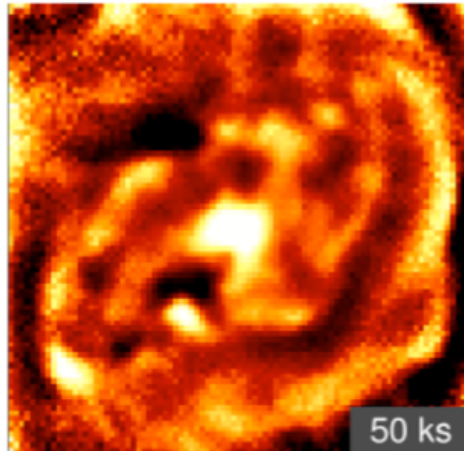
# AGN feedback on cluster scales

- Dissipation of AGN energy into ICM
  - Energy stored in hot gas around bubbles via bulk motions and turbulence
  - History of radio cluster feedback via ripples
  - AGN jet fuelling vs. cooling through temperature distribution
  - Shock speeds of expanding radio lobes

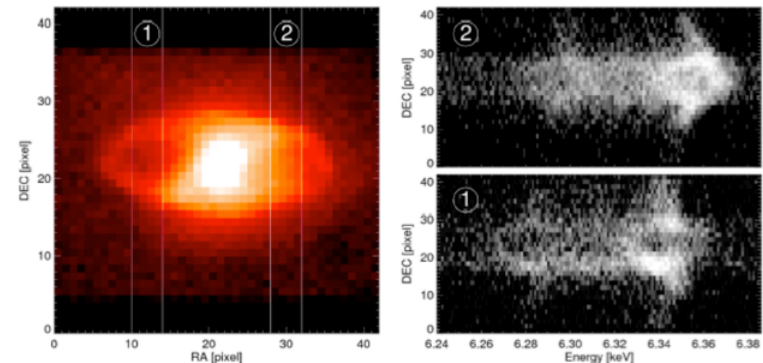


Perseus cluster.  
Courtesy: A.C.  
Fabian

*Athena*/WFI  
unsharp mask  
observation of a  
cluster core at  
 $z=0.05$



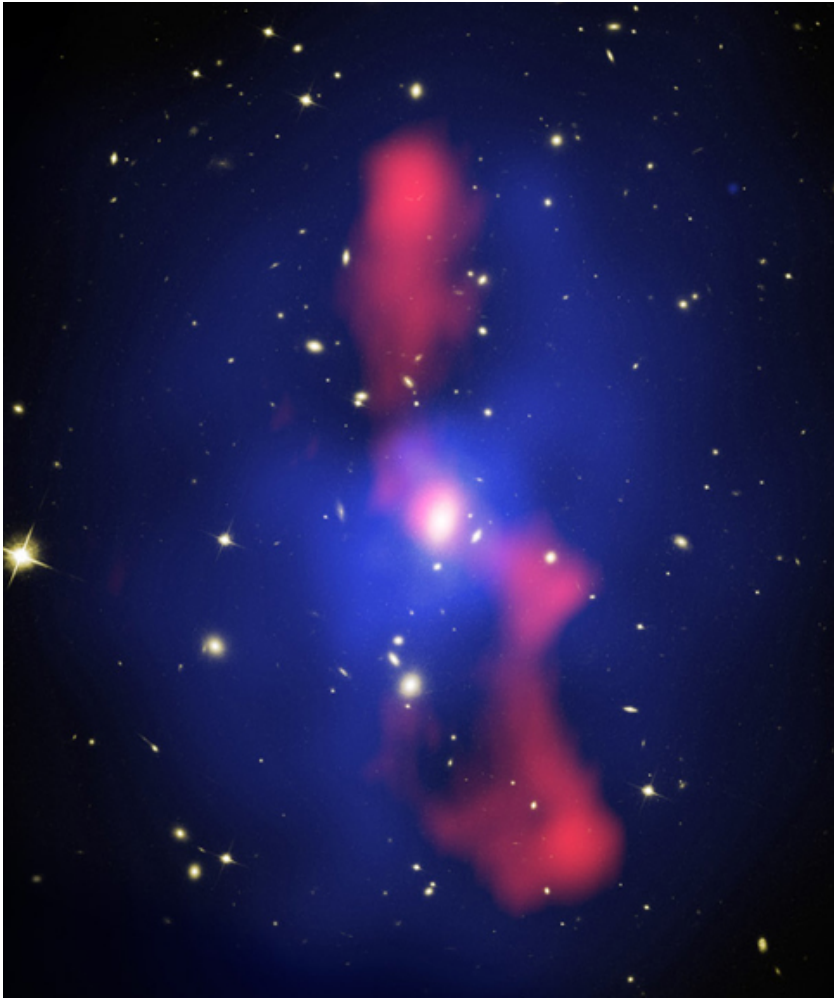
Cygnus A: X-ray image and chosen virtual spectral  
slits (left) and *Athena*/X-IFU spatially resolved  
simulated spectra of the 6.7 keV Fe XXV K $\alpha$  line (right)



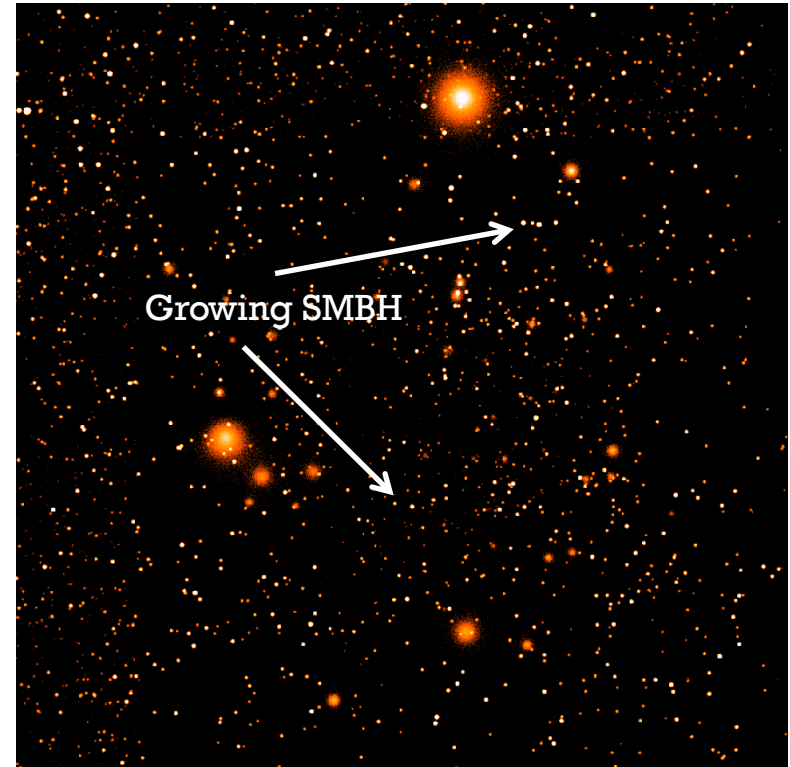
Croston, Sanders et al. 2013 arXiv1306.2323. Simulations by S. Heinz



# The Energetic Universe – Black Holes



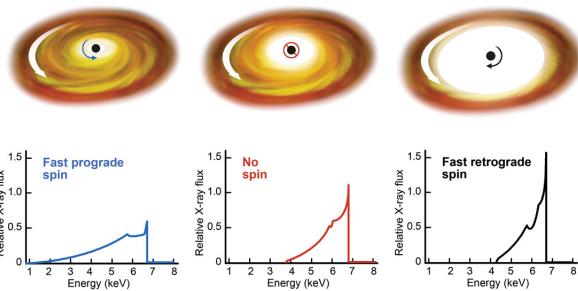
MS0735.6+7421 McNamara et al. 2005



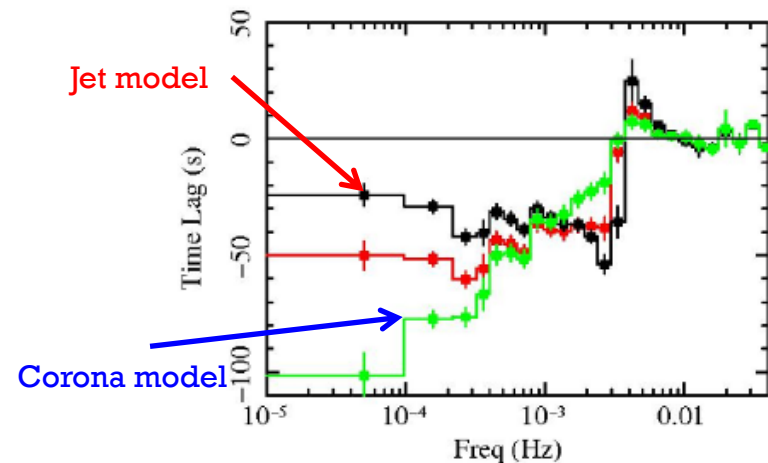
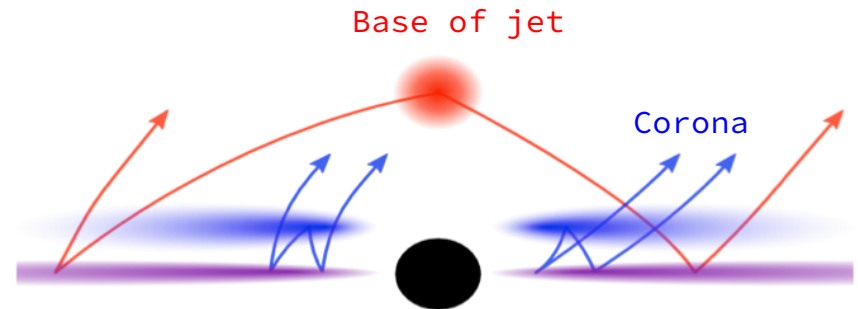
Credit: A. Rau/WFI Team

# Supermassive Black Hole physics

- Measure SMBH spins through Fe line spectroscopy



- Accretion geometry and jet/disk relation through reverberation mapping

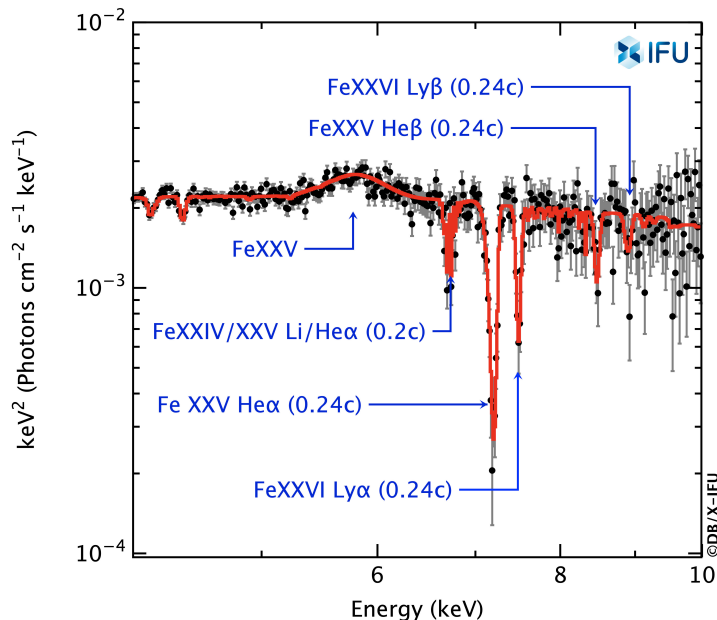


Dovciak, Matt et al. 2013, arxiv:1306.2331

# AGN winds and outflows

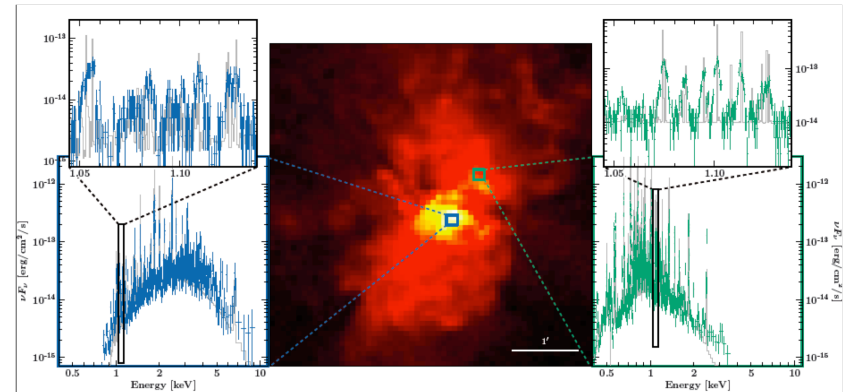
Mechanical feedback effective  
if  $L_{\text{mech}} > 1\% L_{\text{bol}}$

Mechanical energy released  
in ultra-fast outflows  $\propto v^3$



PDS456 100ks X-IFU (X-IFU Consortium)

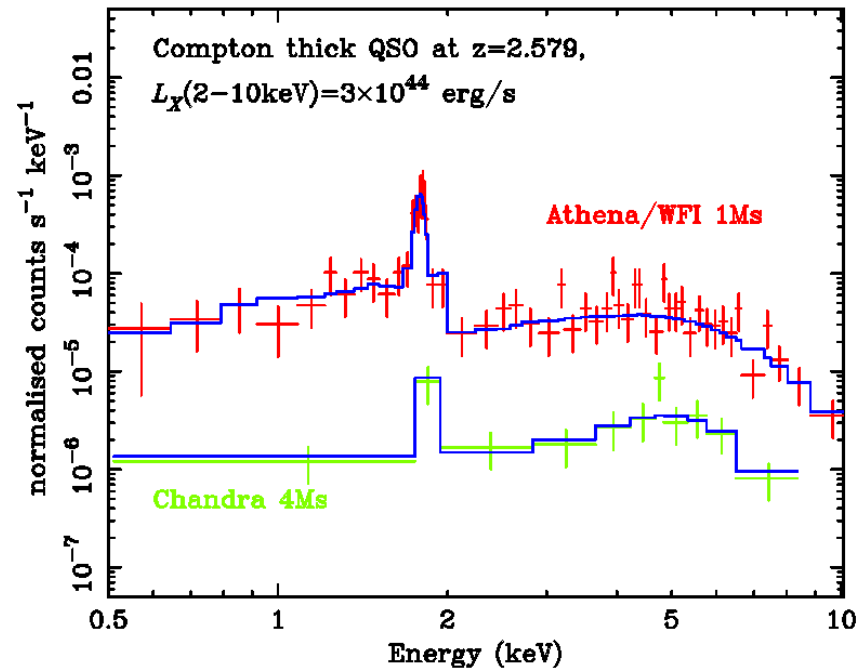
Gas, metals and mechanical energy  
ejected into the circum-galactic  
medium by AGN and Starbursts



A. Ptak and the *Athena* simulation team (in progress)

# Obscured AGN census @ $z \sim 1-3$

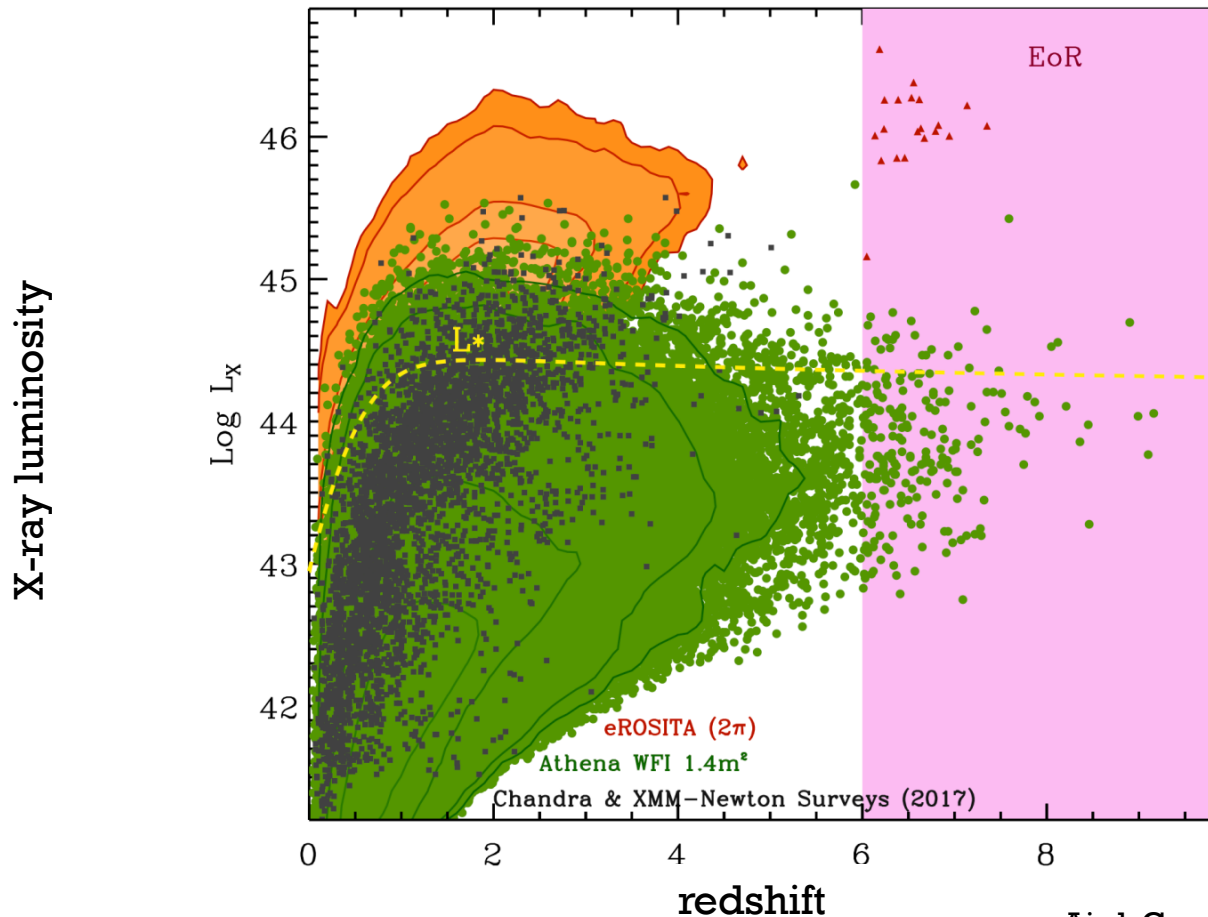
- What is the relation between obscured growth of SMBH through cosmic history and how does it relate to galaxy formation?
- Most SMBH growth expected in heavily obscured (including Compton-Thick) environment
- Best X-ray signature of typical Compton-thick AGN is the Fe emission line, EW  $\sim 0.5-1$  keV
- *Athena*/WFI observations can uncover Compton-Thick average AGN at  $z \sim 3$
- MIR observations can also uncover heavily obscured AGN, but **only** when the AGN is very powerful



Carrera et al. 2018, Athena conference

# Detecting AGN in the Athena survey

AGN  $L_x$  versus  $z$  plane



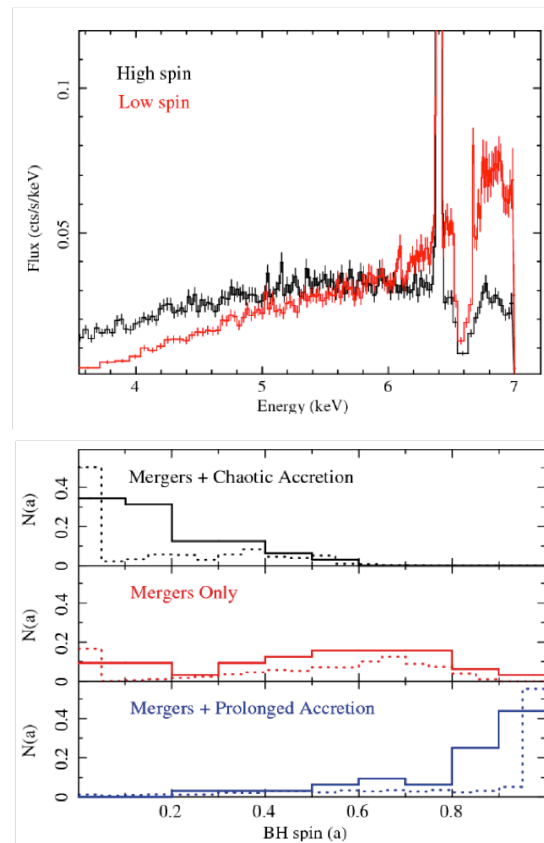
Only most luminous /massive QSOs expected in opt/IR surveys

X-rays needed to signpost typical and obscured AGN

Aird, Comastri et al. 2013 arXiv1306.232  
Updated by Andrea Merloni (MPE) (2017)

# SMBH growth: accretion vs mergers

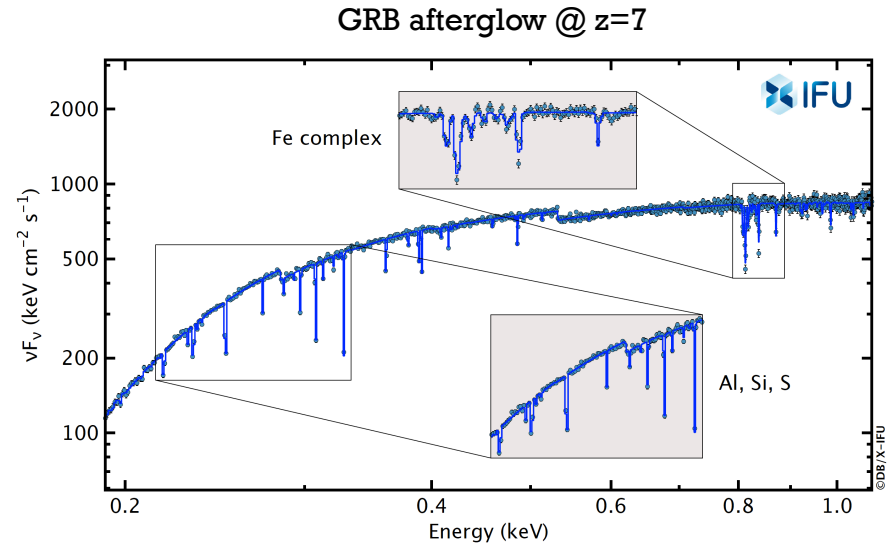
- SMBH spin distribution is highly sensitive to SMBH growth history
  - Accretion spins up SMBH
  - Mergers & chaotic accretion spin down SMBH
- A SMBH spin survey with *Athena* will reveal dominant SMBH growth mode
  - Partly doable with XMM-Newton, but for removal narrow features



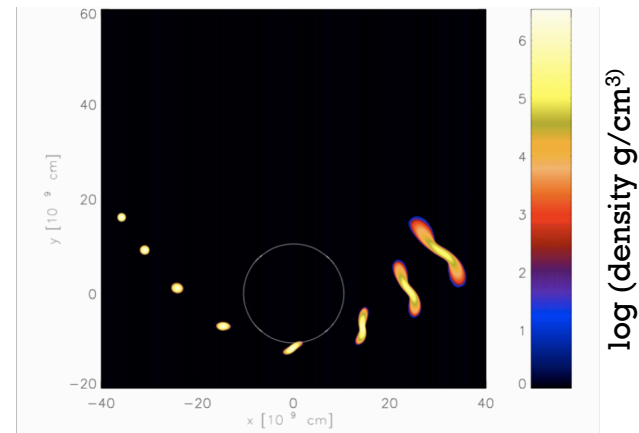
Dovciak, Matt et al. 2013: arXiv 1306.2331  
simulations by G. Miniutti

# Luminous extragalactic transients

- *Athena* will offer fast Target of Opportunity response, whereby a triggered observation could start in  $\leq 4$  hours
  - 40% of GRB afterglows anywhere on the sky can be followed-up by X-IFU with at least 50 ks  $t_{\text{exp}}$
- High- $z$  GRB afterglows will reveal the ISM composition at  $z > 7-10$
- Tidal Disruption Events (TDEs) result from the destruction of a star by a SMBH. *Athena* will
  - Unveil SMBH through this
  - Reveal the composition of the outflowing material
  - Test for the presence of binary SMBH



Courtesy: X-IFU consortium



Jonker, O'Brien et al. 2013: arXiv 1306.2336

Rosswog, Ramirez-Ruiz & Rix (2009)

Courtesy: P.T. O'Brien and P. Jonker

V Meeting of AGN research in Spain,  
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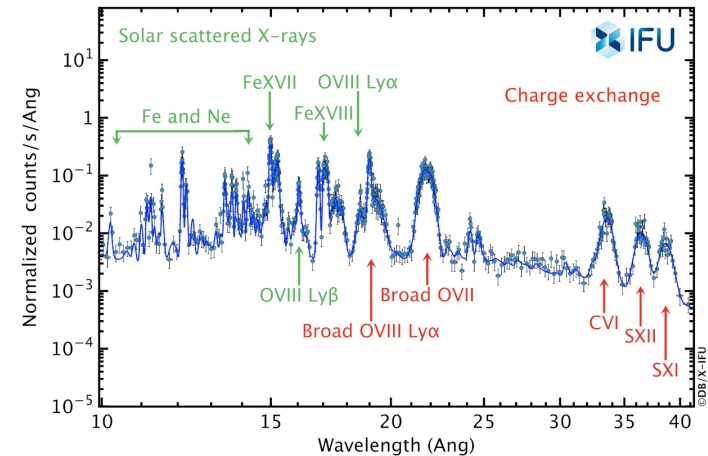




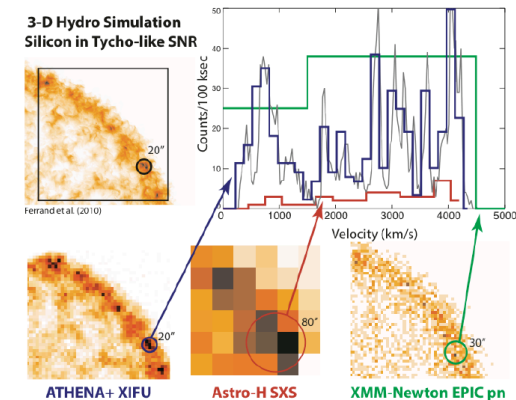
# Observatory and discovery science

- Planets and solar system bodies
- Exoplanets: magnetic interplay
- Star formation, brown dwarfs
- Massive stars: mass loss
- Supernovae: explosion mechanisms
- Supernova remnants: shock physics
- Stellar endpoints (NS)
- Interstellar medium
- Dark matter candidates
- ...

~ 2/3 (TBC) of the *Athena* nominal operational life will be allocated to the international astronomical community through a competitive peer review process



Data courtesy of Graziella Branduardi-Raymont.  
Credits: X-IFU consortium.

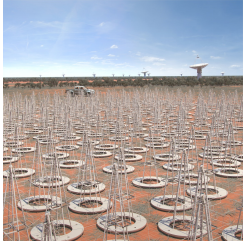


Decourchelle, Costantini et al. 2013: arXiv 1306.2335



# Athena in the framework of the late 2020s

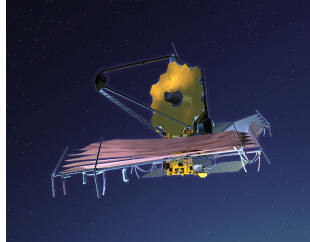
SKA



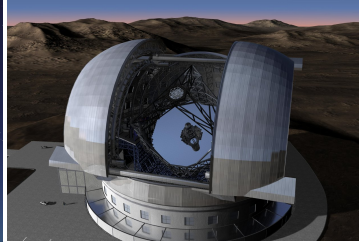
ALMA



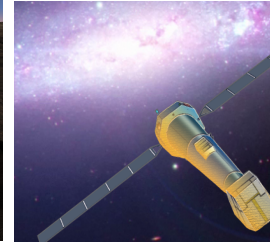
JWST



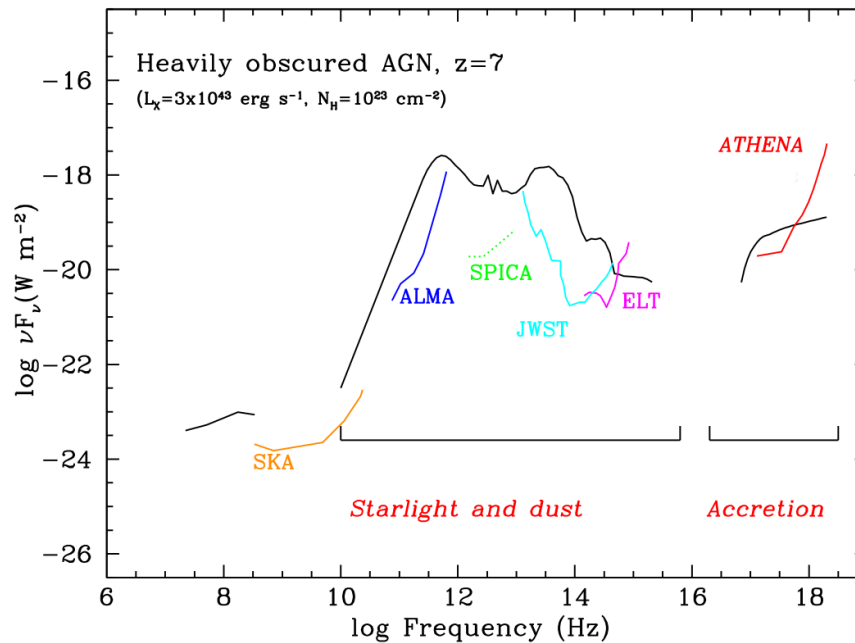
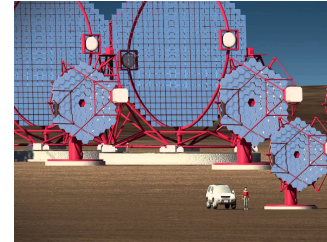
ELT



Athena



CTA

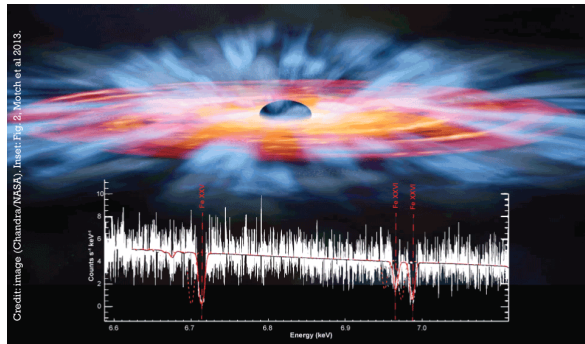


Courtesy: M. Brusa. 2019.

# Athena Synergies with other facilities I

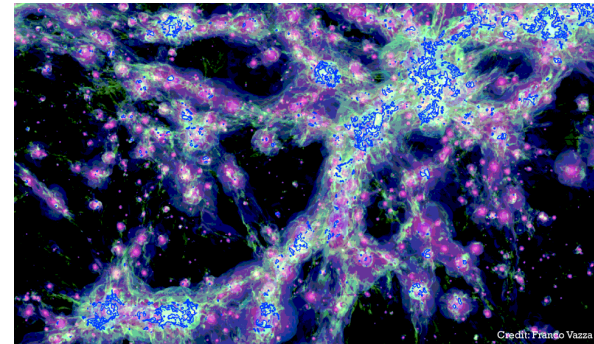
## ■ ESO-Athena

- Led by: P. Padovani (chair), E. Hatziminaglou, M. Díaz-Trigo, S. Viti, S. Ettori, M. Salvato, F. Combes, P. Jonker
- [arXiv:1705.06064](#)
- Early groups & clusters, IM physics, missing baryons, SMBH history, AGN feedback, outflows, transient science, star formation & stars



## ■ SKA-Athena

- Led by: R. Cassano (chair), R. Fender, C. Ferrari, A. Merloni
- [arXiv:1807.09080](#)
- AGN, clusters & transients



# Athena Synergies with other facilities II

## ■ *Athena-Multi-messenger:*

- Led by: L. Piro (chair) ...
- Started with workshop in Nov 2018 in Alicante (Spain)
- *LISA*, *LIGO/VIRGO*, *Theseus*, *KM3NET*, *ICECUBE*, *CTA*
- Compact object mergers, transients (TDE, GRBs), WHIM, SNRs, blazars...
- WP expected by Q3 2020

## ■ *Athena-LSST*

- Led by: M. Watson (chair) ...
- WP expected within 2020

■ ...



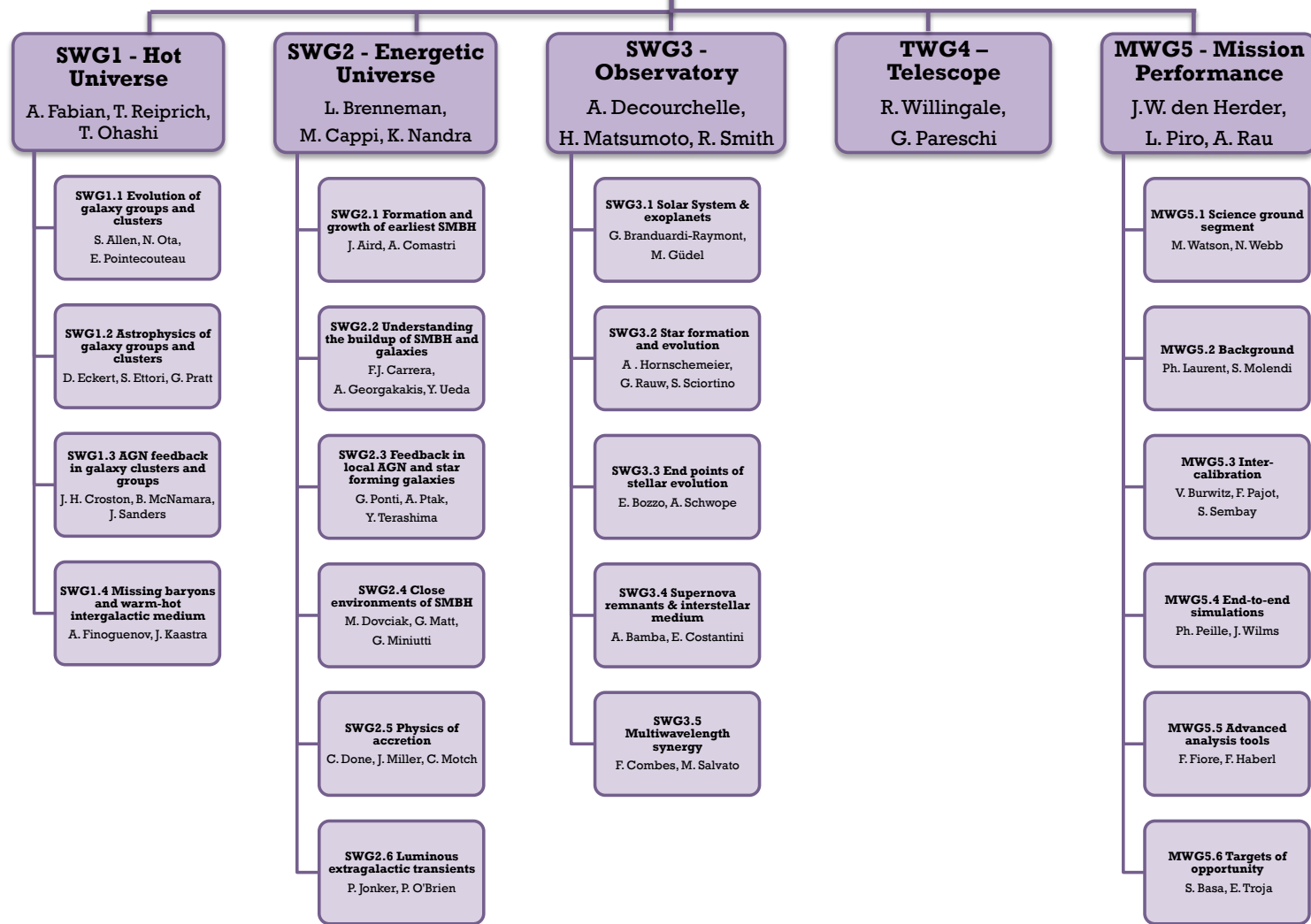
# Athena Science Requirements

Parameter	value	enables (driving science goals)
Effective area at 1 keV	$\geq 1.4 \text{ m}^2$	Early groups, cluster entropy and metal evolution, WHIM, high redshift AGN, census AGN, first generation of stars
Effective area at 6 keV	$0.25 \text{ m}^2$	Cluster energetics (gas bulk motions and turbulence), AGN winds & outflows, SMBH & GBH spins
PSF HEW ( $\leq 7 \text{ keV}$ )	5'' on axis, 10'' off axis	High z AGN, census of AGN, early groups, AGN feedback on cluster scales
X-IFU spectral resolution	2.5 eV 0.2-12 keV	WHIM, cluster hot gas energetics and AGN feedback on cluster scales, energetics of AGN outflows at $z \sim 1-4$
X-IFU FoV	5' effective diameter	Metal production & dispersal, cluster energetics, WHIM
X-IFU background	$< 5 \cdot 10^{-3} \text{ counts/s/cm}^2/\text{keV}$ 2-10keV	Cluster energetics & AGN feedback on cluster scales, metal production & dispersal
WFI spectral resolution	150 eV <80eV (1keV) & <170eV (7keV)	GBH spin, reverberation mapping
WFI FoV	40' x 40'	High-z AGN, census AGN, early groups, cluster entropy evolution, jet-induced cluster ripples
WFI count rate	1 Crab > 80%	GBH spin, reverberation mapping, accretion physics
WFI background	$< 5 \cdot 10^{-3} \text{ counts/s/cm}^2/\text{keV}$ 2-7keV	Cluster entropy, cluster feedback, census AGN at $z \sim 1-4$
Recons. astrometric error	1'' (3s)	High z AGNs
GRB trigger efficiency	50%	WHIM
ToO reaction time	$\leq 4 \text{ hours}$	WHIM, first generation of stars

# Athena Community Organisation

## ESA Athena Science Study Team (ASST)

M. Guainazzi (Chair), K. Nandra (Lead & WFI), D. Barret (X-IFU), A. Decourchelle,  
J. W. den Herder, A.C. Fabian, H. Matsumoto (JAXA), L. Piro, R. Smith (NASA), R. Willingale





# The Athena Community Office

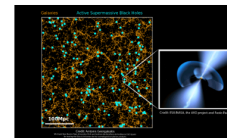
- *Athena* is currently supported by >800 researchers. Their scientific and technical expertise are key for the success of the mission.
- The ASST appointed the *Athena* Community Office to obtain assistance in:
  - Organisational aspects and optimisation of community efforts
  - Keep the *Athena* Community informed
  - Develop communication and outreach activities around *Athena*
- Led by IFCA (CSIC-UC) in Spain, with contributions from IRAP, MPE and UniGe



ATHENA

## Athena Nuggets

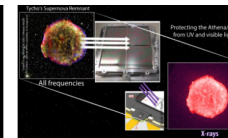
Small pieces of wisdom about scientific and technical topics with the aim of approaching Athena not only to the scientific community but also to the non-experts.  
A single presentation collecting published nuggets with links to their corresponding posts in the social media is offered to the community in several formats: power point, key note and libre office. This presentation will be updated monthly once a new nugget is published.



#AthenaNuggets 24: Connecting supermassive black-holes with the cosmic web

By Antonis Georgakakis (National Observatory of Athens, Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing, Greece)

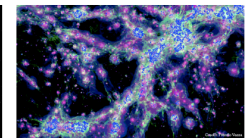
READ MORE



#AthenaNuggets 23: Protecting the Athena/WFI from UV and visible light

By Marco Barbera (Dipartimento di Fisica, Università degli Studi di Milano)

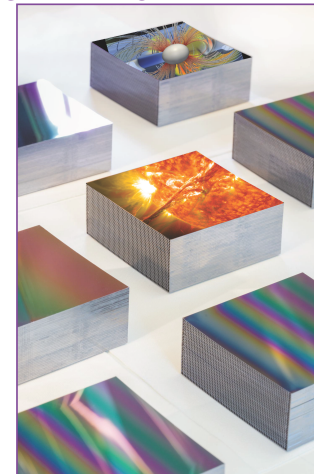
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#AthenaNuggets 22: Athena and the Square Kilometre Array

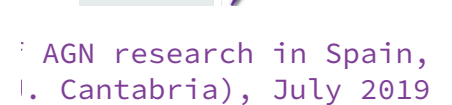
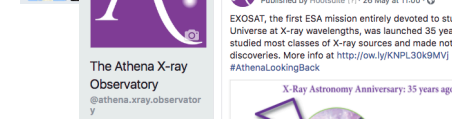
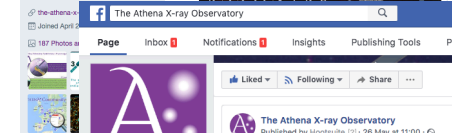
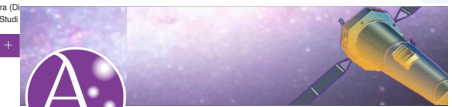
By Antonis Georgakakis (National Observatory of Athens, Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing, Greece)

## ATHENA Community



Newsletter #5

June 2018



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# Athena Project development: Current status

- Phase A ending, last milestone Status Review #1 (January 2018):
  - Comprehensively reviewed the Phase A work performed so far at the system level, including technical, cost and schedule aspects
  - Confirmed the good status of the spacecraft design and identified no showstopper to progressing towards adoption
- A modification of the mission baseline was needed to match mass- and cost-constraints:
  - A 15-row mirror baseline (limited science impact, preserving all major science requirements):
  - Reduction of the effective area at 1 keV from  $2\text{m}^2$  to  $1.4\text{m}^2$
  - Reduction of the nominal life from 5 years to 4 years
- Instrument consortia officially endorsed by ESA (Dec 2018)
- Instrument Preliminary Requirements Reviews (I-PRRs) **successfully passed**:
  - WFI Oct 2018
  - X-IFU Apr 2019



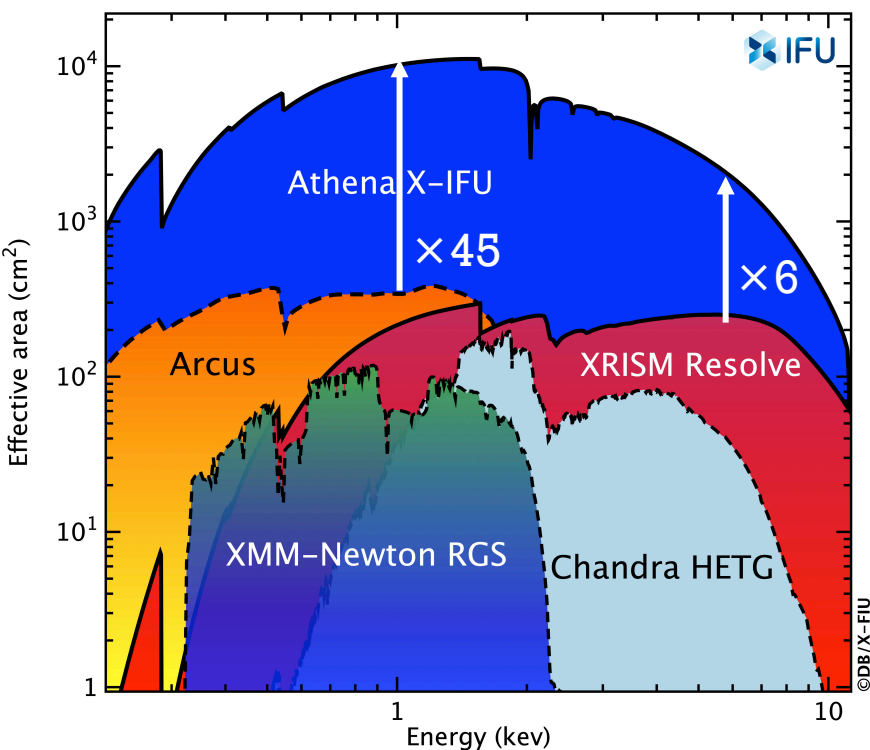
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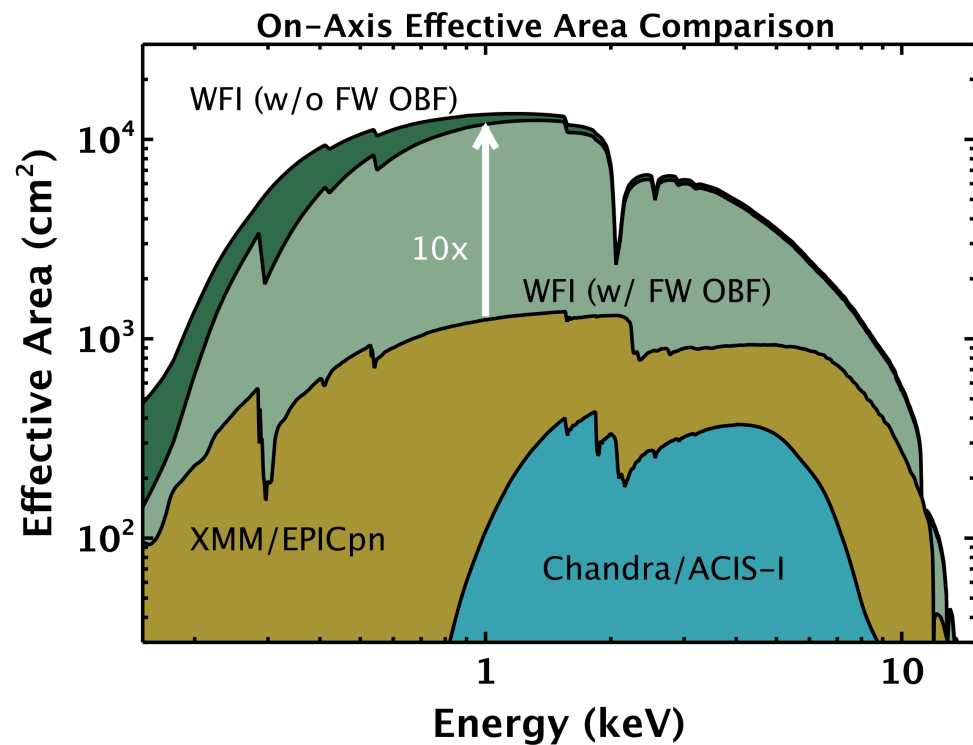
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# Athena is a large effective area mission

X-IFU+mirror collecting area



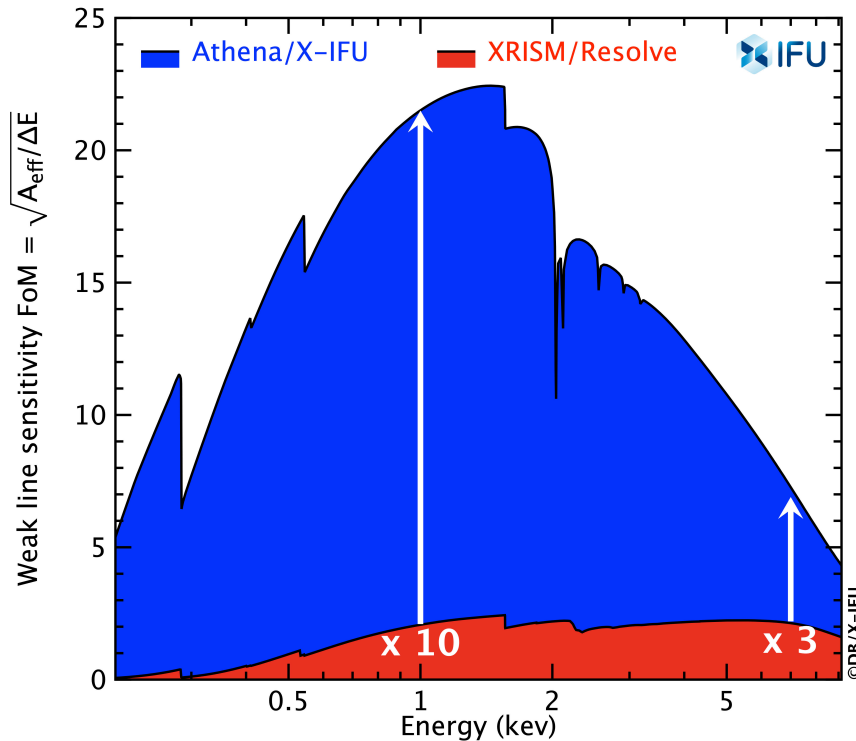
WFI+mirror collecting area



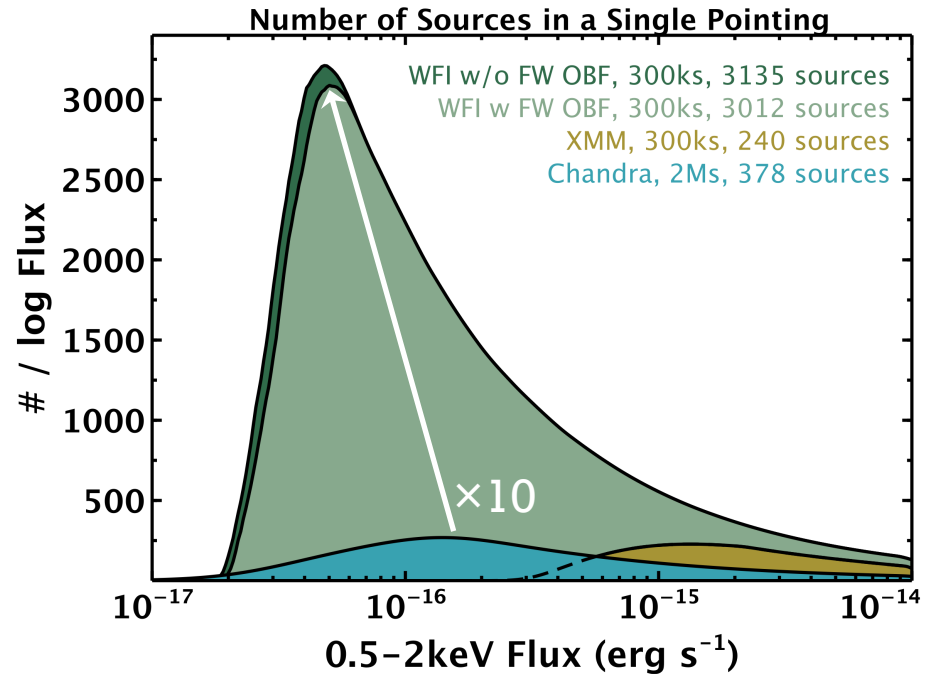
Courtesy A. Rau (MPE)



# Athena: a transformational observatory



Weak line sensitivity comparison between X-IFU and XRISM



Flux distribution comparison between WFI and Chandra deep pointing

Credits: X-IFU team & J. Aird/A. Rau (WFI team)



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# Outlook

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- *Athena* will be a **transformational** X-ray observatory
  - Designed to address the **Hot and Energetic Universe** science theme
  - On the Energetic Universe (AGN):
    - investigate SMBH physics
    - AGN feedback (jets, outflows...)
    - Obscured AGN
    - AGN assembly history...
- Will impact virtually every corner of astronomy
- It will be an essential part of the observational landscape in the early 2030s together with ALMA, ELT, SKA, CTA, LSST, (LISA), etc.
- Vibrant community supporting it
- Key milestones: Phase A completion **Mission Formulation Review Sep 2019**, **Mission Adoption end 2021** and **Launch early 2030s**



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## ■ Follow Athena on

- Web: [www.the-athena-x-ray-observatory.eu](http://www.the-athena-x-ray-observatory.eu)
- Twitter: [@athena2028](https://twitter.com/athena2028)
- Facebook: [The Athena X-ray Observatory](https://www.facebook.com/TheAthenaXrayObservatory)
- Athena Community Office email: [aco@ifca.unican.es](mailto:aco@ifca.unican.es)



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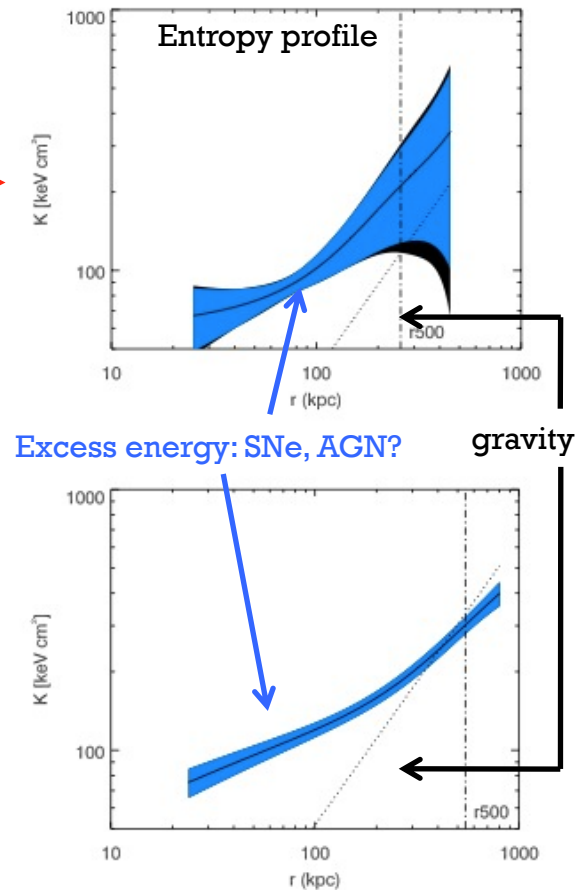
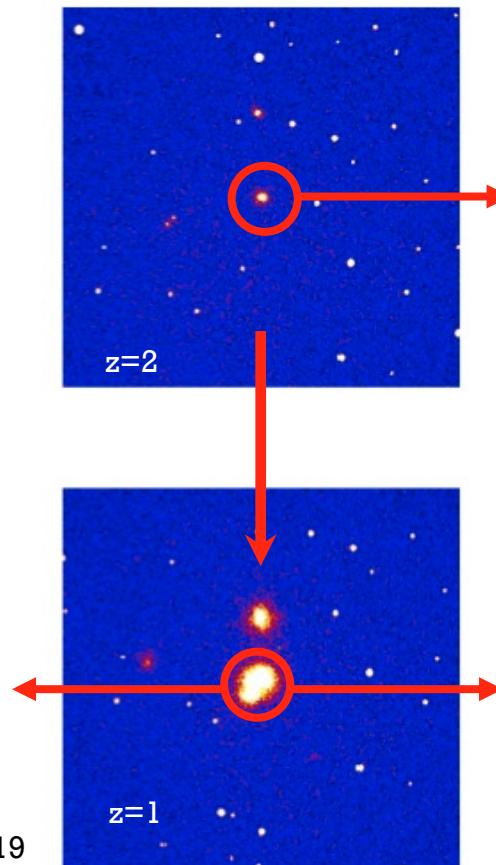
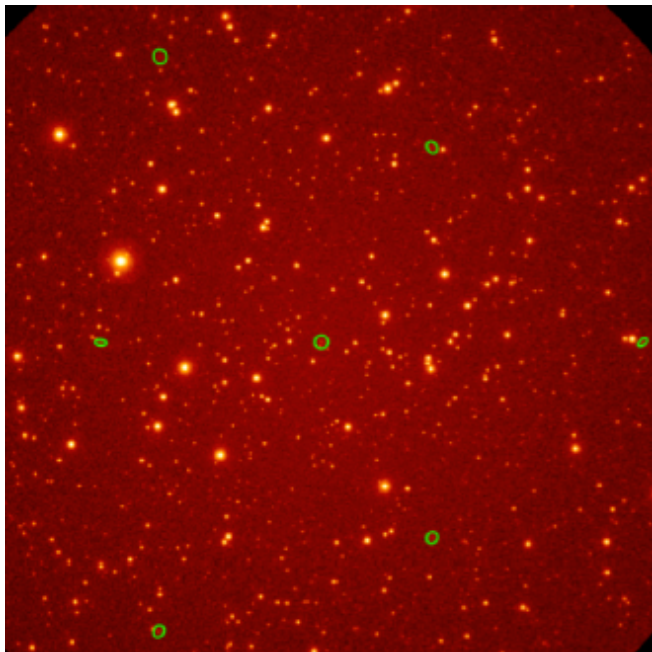
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# Evolution of hot cluster gas

Search for early groups of galaxies at  $z > 2$

Energy deposition history



Ettori, Pratt et al. 2013, arXiv1306.2322

Pointecouteau, Reiprich et al. 2013, arXiv: 1306.2319



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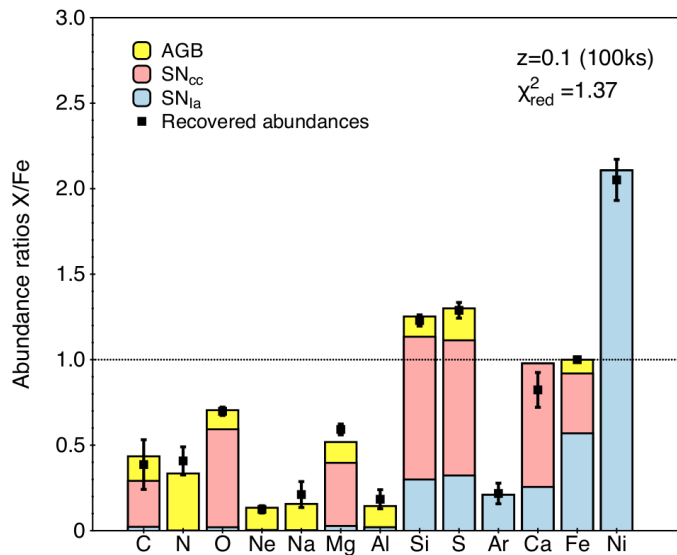
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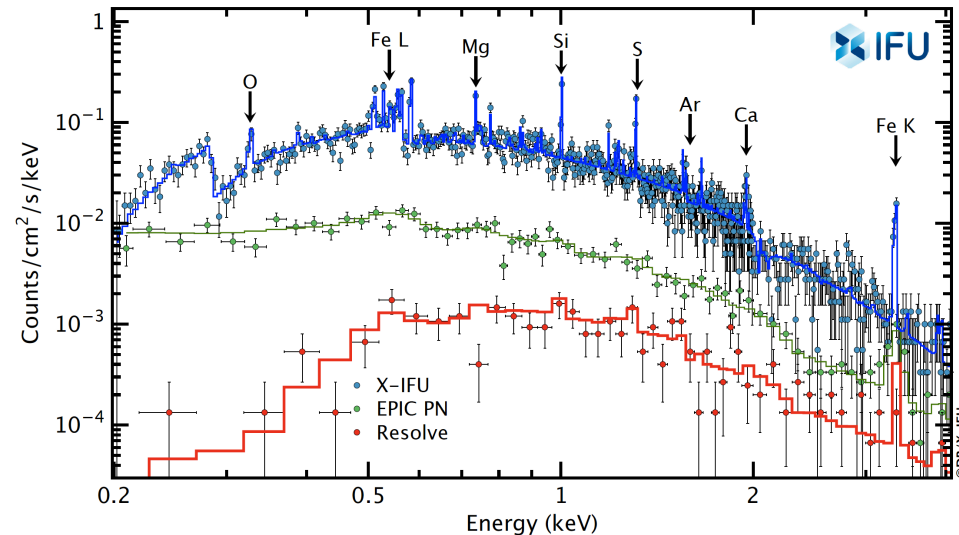
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# Chemical evolution

- Clusters of galaxies are closed boxes, all gas is virialised in the DM potential well
- Cosmic chemical evolution traced by cluster gas
- Constraints on origin of elements and IMF



Galaxy group @ $z=1$   
 150ks *Athena*/X-IFU

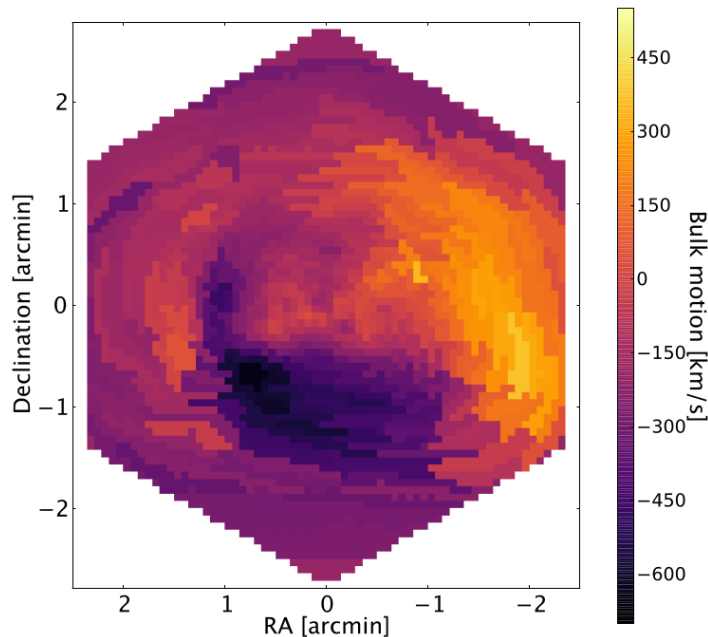


Credits: data courtesy of Etienne Pointecouteau .  
 X-IFU Consortium.

Image courtesy of E. Cucchetti from the X-IFU Consortium. Simulations courtesy: S. Borgani, V. Biffi, K. Dolag, L. Tornatore, E. Rasia - INAF Trieste.

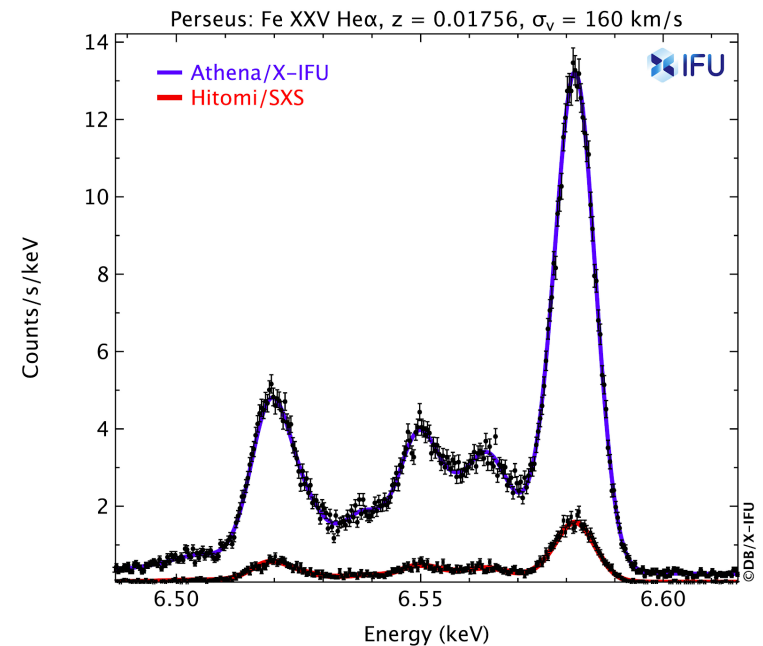
# Cluster bulk motions & turbulence

*Athena* will measure gas bulk motions and turbulence down to 20 km/s



Simulation of the bulk motion map of the hot gas in a galaxy cluster at  $z=0.1$

Credits: X-IFU team (E. Cucchetti, IRAP)

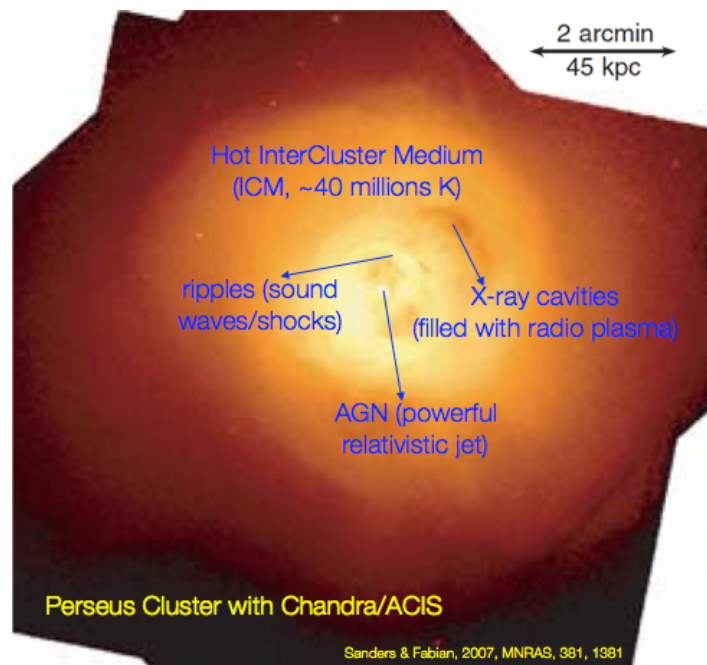


Fe XXV line compared to the one measured with Hitomi Soft X-ray Spectrometer (SXS)

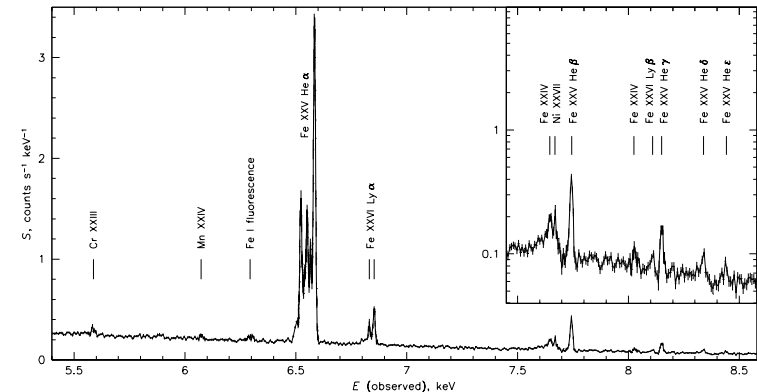
Credits: X-IFU consortium

# Hi-res spectroscopy in action: Hitomi (Feb-Mar 2016)

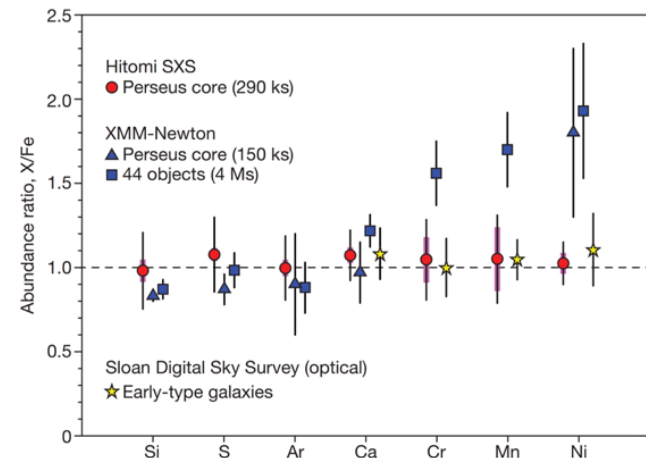
The *Hitomi*/SXS (non-dispersive microcalorimeter) is the first X-ray instrument resolving emission lines in extended sources and measuring their Doppler broadening and shifts



The quiescent intracluster medium in the core of the Perseus cluster. Hitomi Collaboration, Nature, 2016



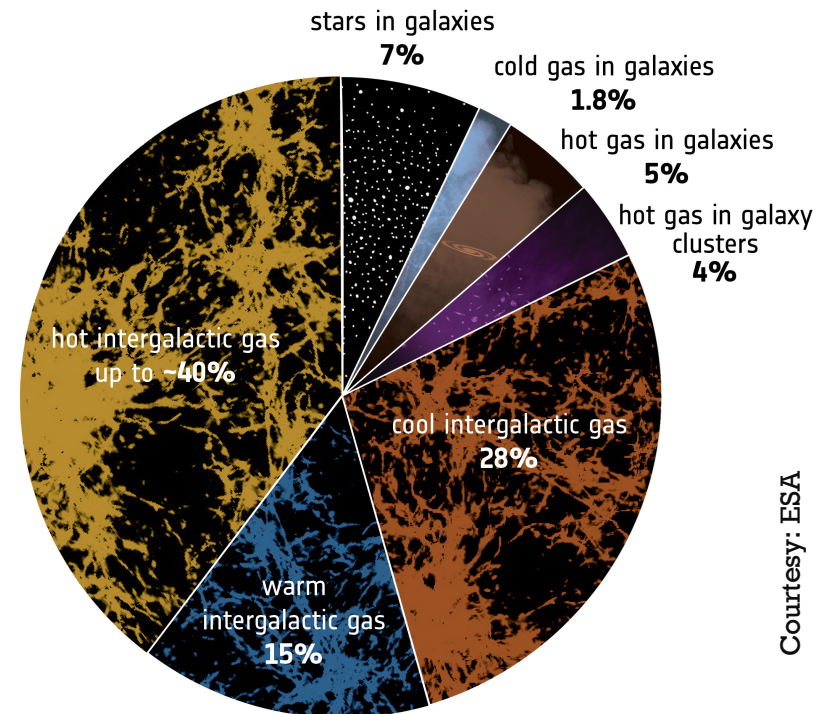
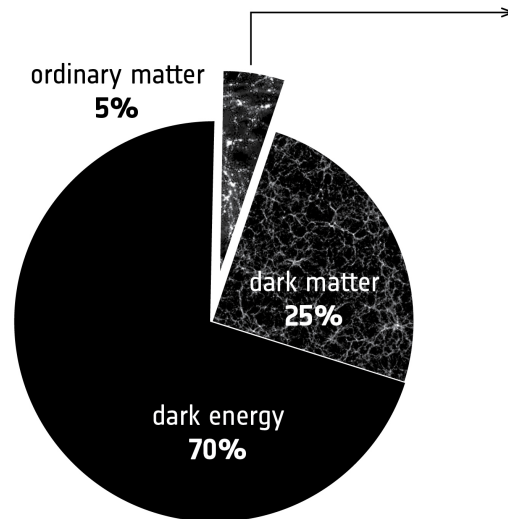
Solar abundance ratios of the iron-peak in the Perseus cluster. Hitomi Collaboration, Nature, 2017





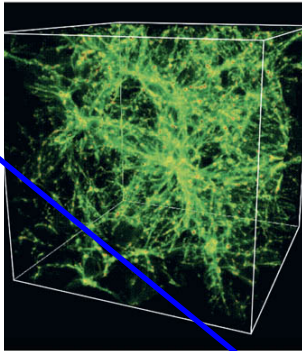
# Missing baryons: the WHIM

- Cosmological hydro simulations show  $\sim 50\%$  of baryons at low redshift at  $T \sim 10^5 - 10^7$  K in the IGM
  - Unvirialised and filamentary distribution
- How can they be detected?
  - In absorption:
    - Against a **bright background sources (AGN or GRB afterglow)**
  - In emission:
    - Tenuous and extended
    - Key to understand CGM and feedback



# Detecting the WHIM baryons in absorption

WHIM filaments against brightest GRB afterglows



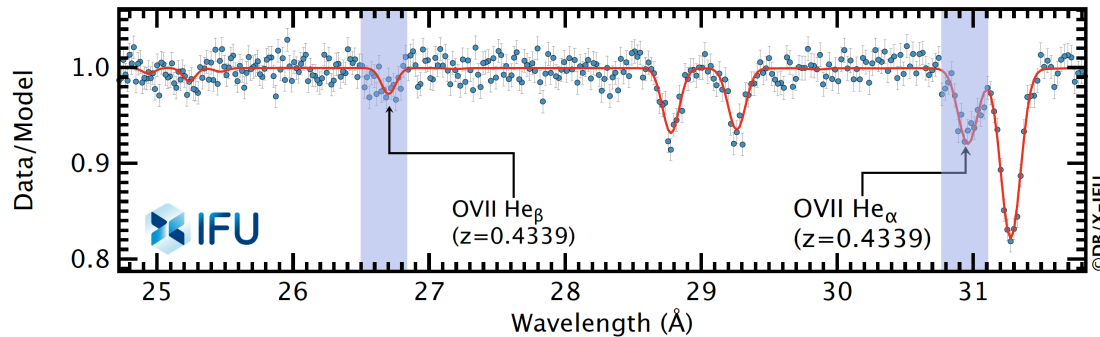
Cen & Ostriker 2006

XMM-Newton finds missing baryons observing a blazar at  $z > 0.4$  !

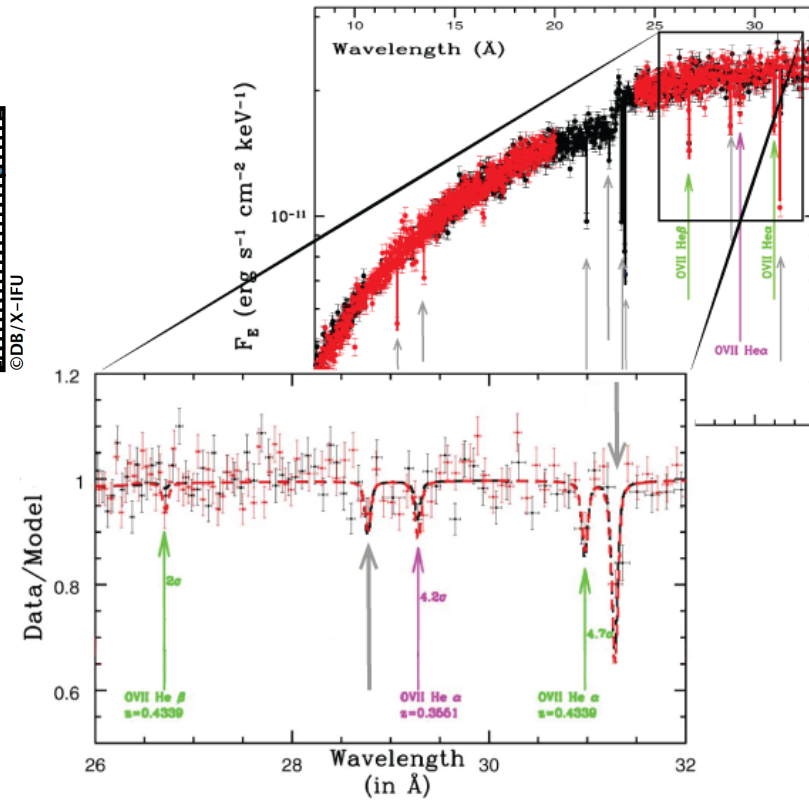
Nicastro et al., Nature, 2018

XMM-Newton/RGS, Blazar  $z > 0.4$ , 1.85Ms

*Athena/X-IFU, same blazar 150ks*



Courtesy: F. Nicastro, X-IFU consortium



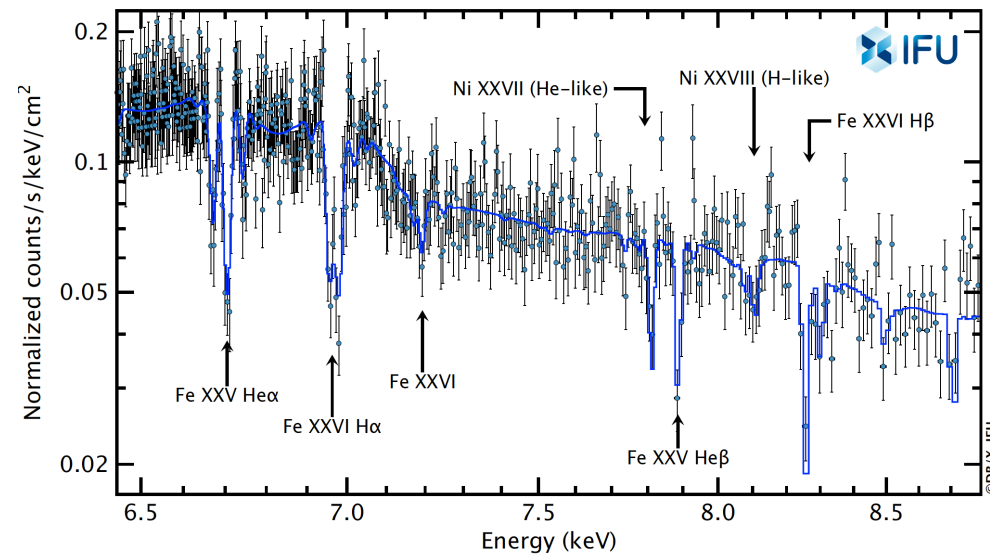
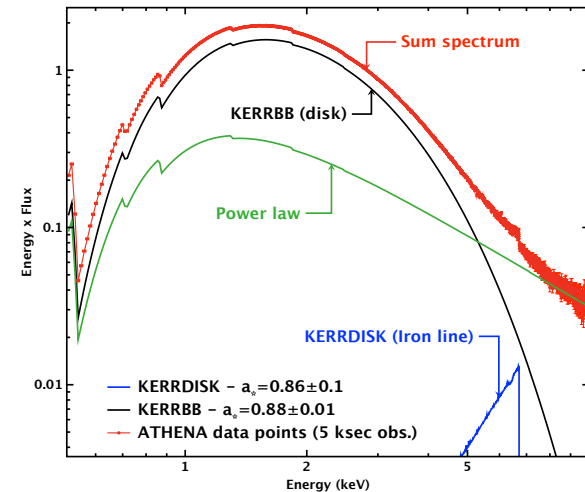
# Stellar black holes

## ■ Measure BH spins

- Constraints on SN origin
- Relation to jets

## ■ Accretion geometry

- Disc truncation from lag spectra
- Winds as diagnostics of the accretion flow



Courtesy J.M. Miller and the X-IFU consortium

# Chasing the transient Universe with Athena

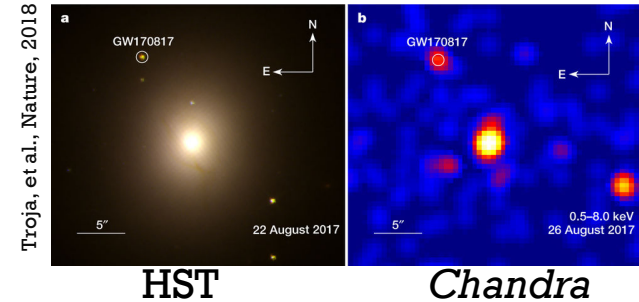
- X-rays probe:

- Jet: GRB afterglow (from radio to X-rays)
- Isotropic features:
  - Off-axis (orphan) afterglows
  - Cocoon

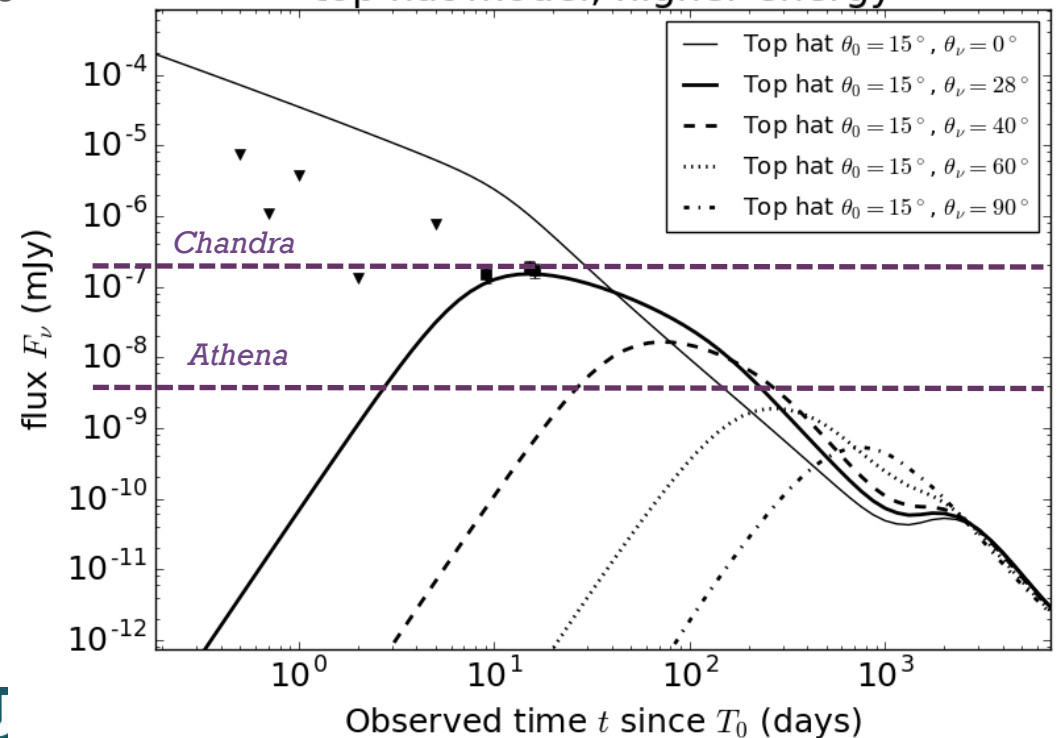
- Beaming angle  $\sim 1/\Gamma$

*Athena* needed for any  
line-of-sight  $\geq 40^\circ$   
( $\sim 70\%$  of potential GRBs)

## GW170817 counterpart



## top hat model, higher energy



Courtesy L. Piro (IAPS/INAF)

# Athena science objectives

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- Each broad science topic is translated into specific **science objectives**
  - Observing this-many objects of such-and-such type with such-and-such properties to understand their origin
  - e.g. R-SCIOBJ-221 Complete AGN census: Athena shall determine the accretion energy density in the Universe, by measuring the X-ray luminosity function and obscuration properties of the AGN population with at least 10 Compton thick AGN per luminosity bin (0.5dex) and redshift bins ( $\Delta z = 1$ ) up to redshift  $z \sim 3.5$
- Many of those concern observations of limited samples of objects of specific types
- But others require assembling those samples (rare objects, elusive objects...)
- To ensure these objectives are reached, the Athena team has assembled a **Mock Observing Plan**
  - Minimum set of observations that would yield those results within the lifetime of the mission (nominally 4y)
  - Also used to dimension engineering parameters (fuel...)



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# The Athena survey I

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- Part of the Mock Observing Plan that provides samples of newly detected/characterized sources for some science objectives
  - Detection and characterisation of galaxy groups and clusters at  $z > 2$
  - Detection of AGN at  $z \sim 6-8$
  - Characterisation of Compton-thick AGN at  $z \sim 1-3$
  - Prevalence of Warm Absorbers and UFOs among the  $z \sim 1-3$  AGN population
  - ....
- From XMM-Newton/Chandra experience:
  - Some originated in Guaranteed Time and continued by the community
  - Many proposed and developed by the community
  - In coordination/synergy with other multi-wavelength facilities (EUCLID...)



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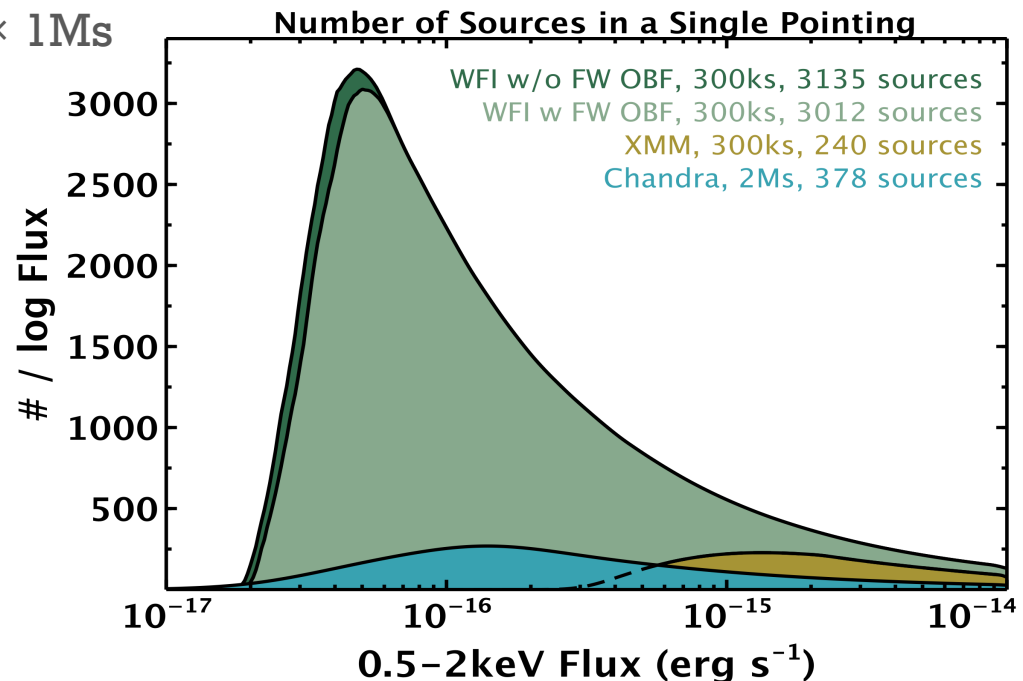


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# The Athena survey II

- To be carried out with WFI
- Structured in several depths:
  - Wide “shallow” survey:  $\sim 100\text{s} \times 10\text{s ks}$  (10s of  $\text{deg}^2$ )
  - Narrow deeper survey:  $\sim 10 \times 100\text{s ks}$  (a few  $\text{deg}^2$ )
  - Pencil beam deep survey:  $\sim 4 \times 1\text{Ms}$



# The Athena survey: definition

---

- Several incarnations as the science objectives evolved with the mission capabilities
  - Effort led by J. Aird with many contributors (A. Comastri, G. Lanzuisi, A. Georgakakis, Y. Ueda, S. Allen, N. Ota, E. Pointecouteau, L. Brenneman, M. Cappi, T. Reiprich, A. Rau, FJC...)
- How do we operate for source detection:
  - Simulate background: particle + Gal + “diffuse xgal” + sources from synthesis model
  - Drop/simulate our sources (galaxy clusters, AGN) on top of that
  - Detect sources
- How do we operate for source characterisation:
  - Simulate background spectrum: particle + Gal + “diffuse xgal”
  - Simulate source background
  - Model simulated background



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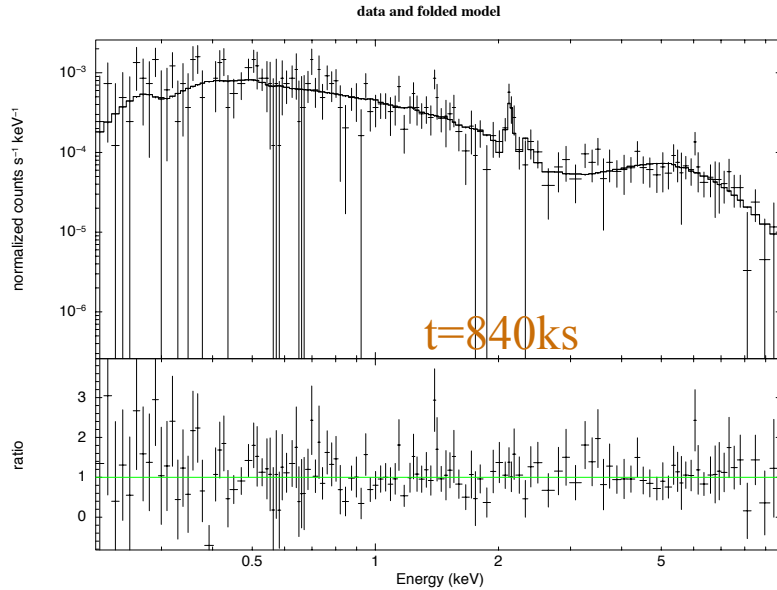
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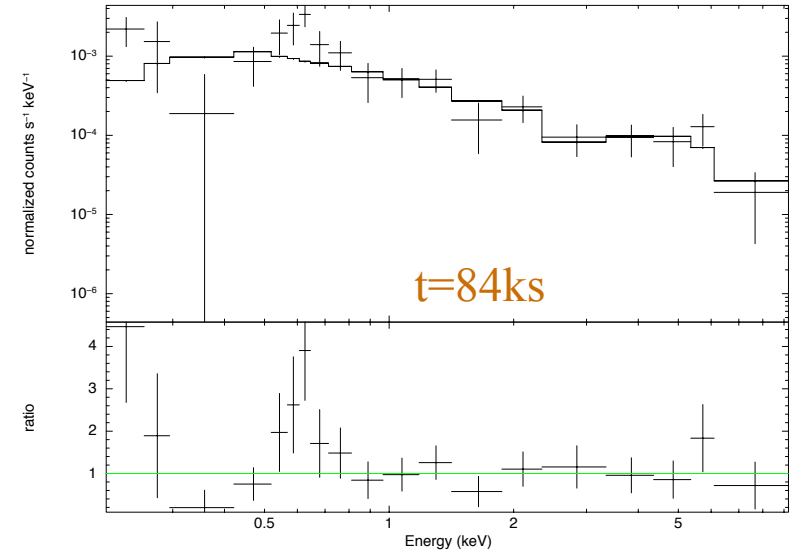
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# The Athena survey: definition

$\log N_H = 24.5$   
 $L_X(2-10\text{keV}) = 5 \times 10^{44} \text{ cgs}$   
 $z=2$



carrera 18-Sep-2018 18:02



carrera 18-Sep-2018 18:02

- How do we operate for source characterisation:
  - Simulate background spectrum: particle + Gal + “diffuse unresolved xgal”
  - Simulate source spectrum + background
  - Model simulated spectrum

# The Athena survey: geometry

---

- As proposed:  $4 \times 1\text{Ms} + 3 \times 700\text{ks} + 7 \times 600\text{ks} + 289 \times 80\text{ks} = 33.42\text{ Ms}$
- As of May 2018:  $14 \times 840\text{ ks} + 106 \times 84\text{ ks} = 20.66\text{ Ms}$ 
  - Using  $1.4\text{m}^2$  mirror,  $5''$  HEW PSF on axis, 2.3mm rib spacing, WFI with filter
  - Deeper depth driven by  $L^*/10$  AGN @ $z=6-7$ ,  $L^*$  CT AGN @ $z=1-3$  ( $L, N_H$ )
  - Wider area driven by gal. groups @ $z>2$  (T),  $\lesssim L^*$  AGN @ $z=7-8$ , WA in  $L^*$  AGN @ $z=3$ , UFO in  $\lesssim L^*$  AGN @ $z=4$



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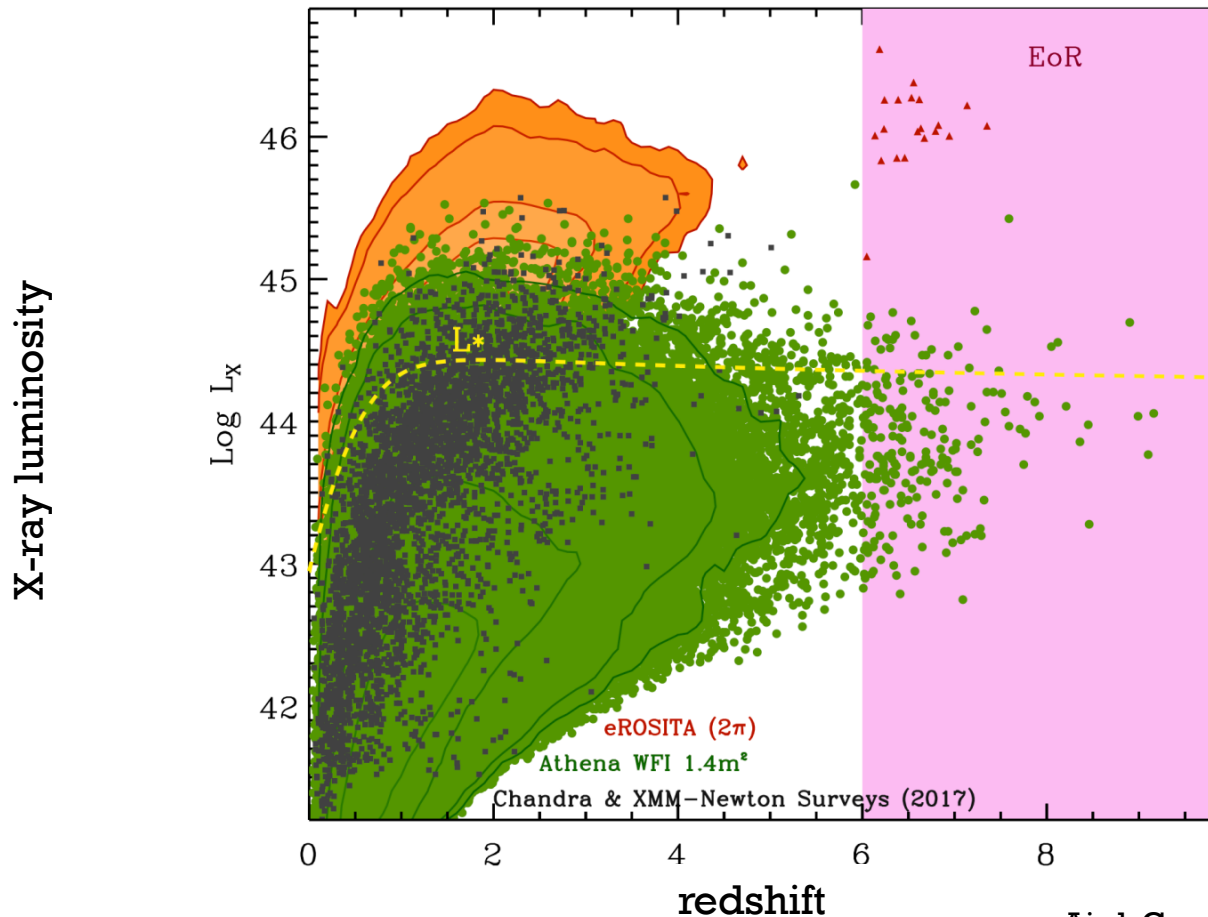
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# Detecting AGN in the Athena survey

AGN  $L_X$  versus  $z$  plane



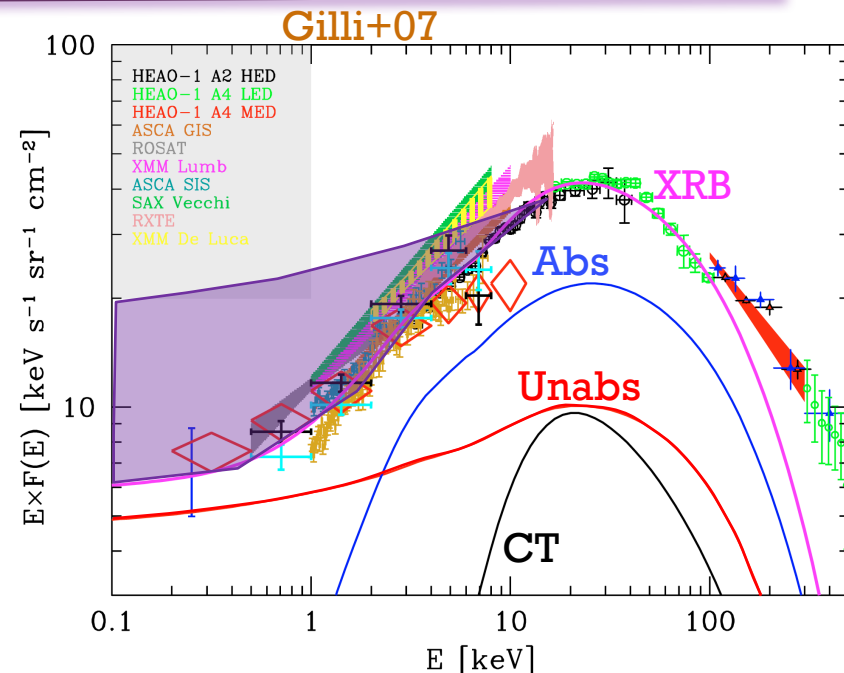
Only most luminous  
/massive QSOs  
expected in opt/IR  
surveys

X-rays needed  
to signpost typical  
and obscured AGN

Aird, Comastri et al. 2013 arXiv1306.232  
Updated by Andrea Merloni (MPE) (2017)

# Obscured AGN: why care?

- Most energy emitted from accretion in the Universe is obscured
- Relationship between build-up of SMBH and growth of host galaxies:
  - through obscured phase  $z \sim 1-4$

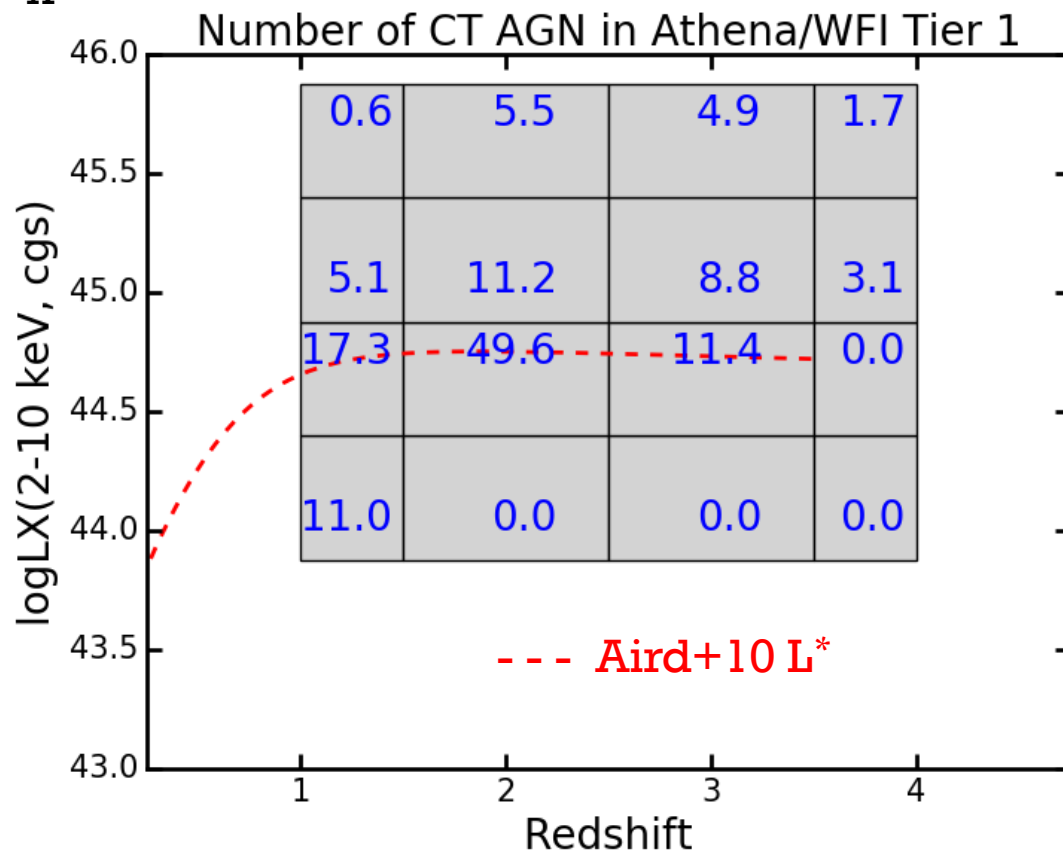


- **Unclear (but significant)** contribution of Compton Thick (CT) objects
- One possible mechanism of direct influence of AGN on host galaxy: **outflows** (also radiation and **jets**, but another SWG)
  - Warm absorbers (WA)
  - Ultra-Fast Outflows (UFO)



# Heavily obscured (CT) AGN

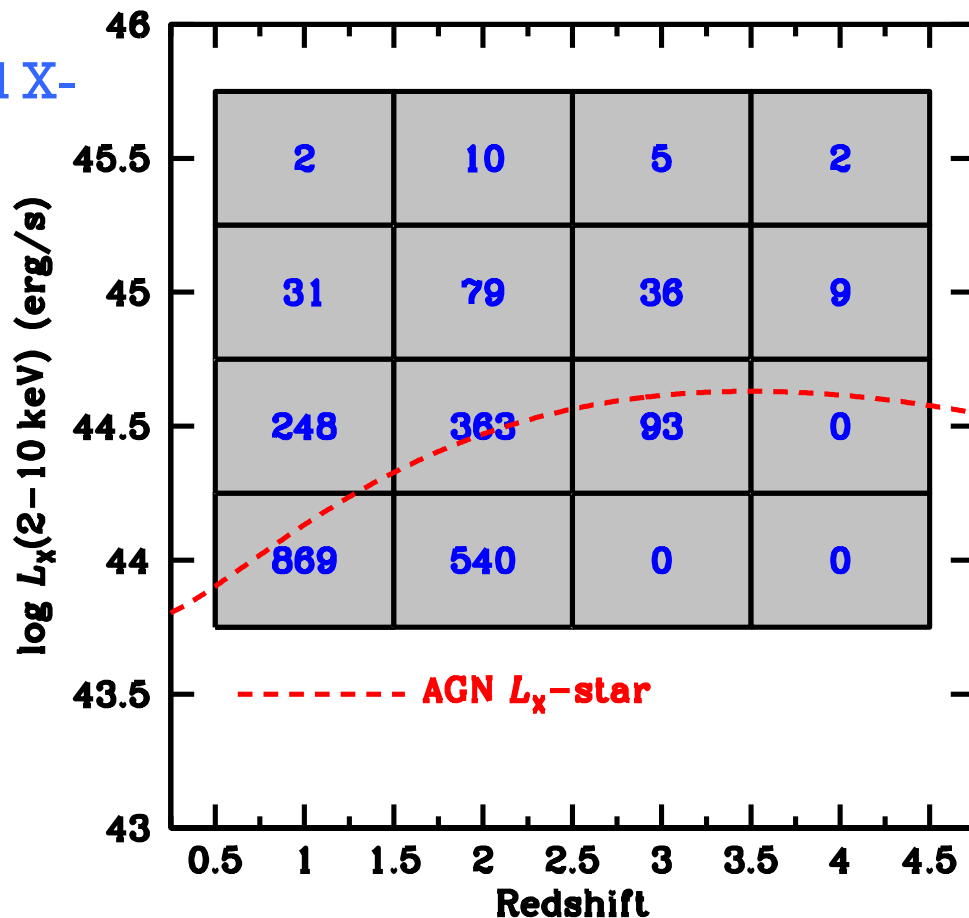
- Complete census of heavily obscured (dominant?) AGN
- Recovering within 30%  $L_X$  and  $N_H$  (CT:  $\log(N_H/\text{cm}^{-2})=24.5, 25.5$ ) **using only WFI spectrum and  $z$**
- Brightman&Nandra'11 torus
- Gilli+07 CXB model
- Including stray light
- **Can do it for  $L^*$  for  $z \leq 3$**
- Of course, in “real life” synergies with multi- $\lambda$  data



# Ionised absorption in AGN

- **Aims:**
  - Determine incidence of WA in general population of AGN
  - Provide targets for detailed X-IFU studies
- Recovering within 50%  $\log \xi(2-4)$  and  $N_{\text{H,ion}}$  ( $\log(N_{\text{H,ion}}/\text{cm}^{-2})=22-24$ ) **using only WFI spectrum**
- Ueda+03 XLF, 40% WA (Blustin+05)
- Using wide (60ks) tier of survey
- **Can do it for  $L^*$  for  $z \leq 3$**

expected number of WA in Athena/WFI surveys



Credit: A. Georgakakis

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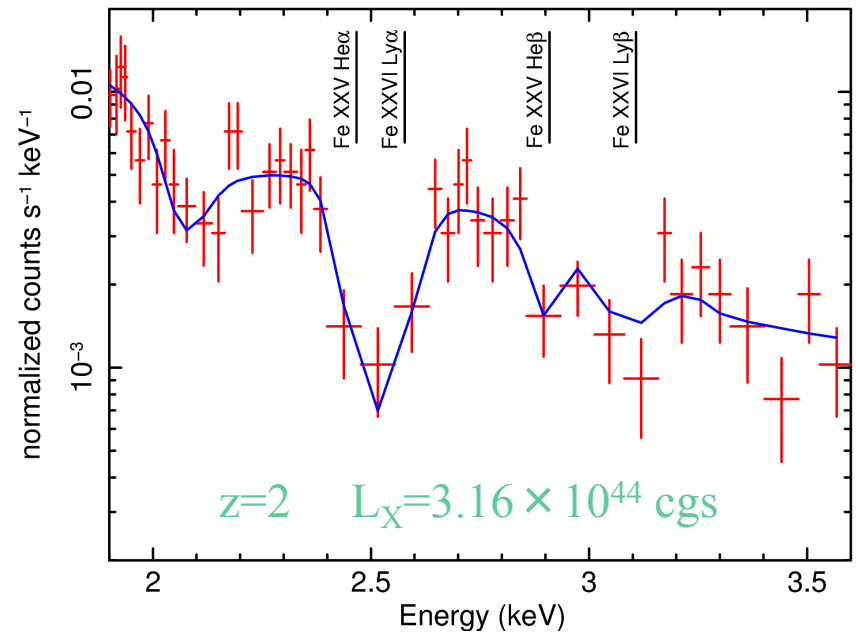
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# Ultra-Fast Outflows in AGN

- Determine incidence, duty cycle and energetics of UFOs
- Detecting 6.7keV abs. feature at  $>5\sigma$  **using only WFI spectrum**
- $\log\xi=3.5$ ,  $\log(N_{\text{H,ion}}/\text{cm}^{-2})=24$ ,  $v_{\text{turb}}=3000 \text{ km/s}$ ,  $v_{\text{out}}=0.1c$  **Lanzuisi+12**
- **Ueda+03** XLF, 30% UFO (**Tombesi+10**)
- Using wide (84ks) tier of survey: **transient**
- **Can do it for  $\log(L_{\text{x}}/\text{erg/s})\geq 44.5$  for  $z\leq 4$**

Credit: G. Lanzuisi



# Ultra-Fast Outflows in $ACM$

- Determine incidence, duty cycle
- Detecting 6.7keV abs. feature at  $>5\sigma$  **using only WFI spectrum**
- $\log \xi = 3.5$ ,  $\log(N_{\text{H,ion}}/\text{cm}^{-2}) = 24$ ,  $v_{\text{turb}} = 3000 \text{ km/s}$ ,  $v_{\text{out}} = 0.1c$  **Lanzuisi+12**
- Ueda+03** XLF, 30% UFO (**Tombesi+10**)
- Using wide (84ks) tier of survey: **transient**
- Can do it for  $\log(L_x/\text{erg/s}) \geq 44.5$  for  $z \leq 4$**

